FINAL REPORT:
SISKIYOU COUNTY CULVERT INVENTORY AND FISH PASSAGE EVALUATION

By

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ACKNOWLEDGEMENTS **2**

INTRODUCTION **4**

FINAL PRODUCT OF CULVERT INVENTORY 5
PROJECT JUSTIFICATION 6

METHODS AND MATERIALS **9**

LOCATION OF CULVERTS 9
INITIAL SITE VISITS 9
Culvert Location *10*
Longitudinal Survey *10*
Channel widths *12*
Fill Estimate: *12*
Other Site-specific Measurements *14*
DATA ENTRY AND PASSAGE ANALYSES 15
FIRST-PHASE PASSAGE EVALUATION FILTER: GREEN-GRAY-RED 15
FishXing Overview *18*
Hydrology and Design Flow *20*
Peak Flow Capacity *20*
Fish Passage Flows *21*
SITE VISITS FOR FISH MIGRATION OBSERVATIONS 22
HABITAT INFORMATION 23
INITIAL RANKING OF STREAM CROSSINGS FOR TREATMENT 24
Ranking Criteria *24*

RESULTS **27**

INITIAL SITE VISITS 27
PASSAGE ANALYSES 35
FISH OBSERVATIONS 40
RANKING MATRIX 42
SITE-SPECIFIC TREATMENTS AND SCHEDULING 48
High-Priority Sites *48*
CDFG Allowable Design Options (from Heise 2001) *48*
NMFS Order of Preferred Alternatives *51*
Moderate-Priority Sites *51*
Low-Priority Sites *52*

LITERATURE CITED **53**

PERSONAL COMMUNICATIONS **55**

INTRODUCTION

The inventory and fish passage evaluation of road crossings within the Siskiyou County road system was conducted between August, 2000 and March, 2002 under contract with the California Department of Fish and Game (CDFG) (contract # **P9985047**). The primary objective was to assess passage of juvenile and adult salmonids and develop a project-scheduling document to prioritize corrective treatments to provide unimpeded fish passage at road/stream intersections. The inventory was limited to county-maintained crossings within anadromous stream reaches within the Klamath River known to historically and/or currently support runs of coho salmon (*Oncorhynchus kisutch*), chinook salmon (*O. tshawytscha*) and/or steelhead (*O. mykiss irideus*).

The inventory and assessment process included:

1. Locating stream crossings within anadromous stream reaches.
2. Visiting each crossing on an initial site visit to determine the type of crossing and assessment of stream channel as suitable fish habitat.
3. At county-maintained sites with culverts - collecting information regarding culvert specifications and surveying a longitudinal profile.
4. Assessing fish passage using culvert specifications and passage criteria for juvenile and adult salmonids (from scientific literature and FishXing computer software);
5. Assessing quality and quantity of stream habitat above and below each culvert; and
6. Assessing fish passage by direct observation at culvert sites during fall/winter migration period.

The prioritization process ranked culvert sites by assigning numerical scores for the following criteria:

1. Presumed species diversity within stream reach of interest (and federal listing status).
2. Extent of barrier for each species and lifestage for range of estimated migration flows.
3. Quality and quantity of potential upstream habitat gains.
4. Sizing of current stream crossing (risk of fill failure).
5. Condition of current crossing (life expectancy).

The initial ranking was not intended to provide an exact order of priority, rather produce a first-cut rank in which sites could be grouped as high, medium, or low priority. Professional judgment was a vital component of the ranking process. Site-specific information that is difficult to assign a discrete numerical value was also considered.

Examples included:

1. Direct observations of attempted migration at known barriers. Treating these sites should result in a high probability of immediate utilization of re-opened habitat.

2. Fish behavior at culverts. Recent studies suggests salmonids experience migration difficulties at road crossings that exhibit hydraulic characteristics within the reported abilities of several salmonid species (Taylor 2000; Love pers. comm.).

3. Physical stress or danger to migrating salmonids. Recent studies have revealed numerous sites in northern California where concentrations of migrating salmonids were subjected to decades of predation by birds and mammals or poaching by humans (Taylor 2000). Inability to enter coolwater tributaries to escape stressful/lethal mainstem water temperatures during summer months has also been observed. These factors should weigh heavily in priority ranking.

Additional physical, operational, social, and/or economic factors exist that may influence the final order of sites; but these are beyond the scope of this project.

Final Product of Culvert Inventory

A hard copy and a CD of this project-scheduling document were distributed to the following agencies and departments: Siskiyou County Department of Transportation (2 copies); CDFG- Inland Fisheries Division and Region 1 Office (copy for each office); and Five-Counties Salmon Group.

Final report includes:

1. A count and location of all culverted stream crossings. Locations were identified by stream name; road name; watershed name; mile marker or distance to nearest crossroad; Siskiyou county road map #; USGS Quad name; Township, Range and Section coordinates; and lat/long coordinates. All location data were entered into a spreadsheet for potential database uses.

2. For each site, culvert specifications were collected, including: length, diameter, type, position relative to flow and stream gradient, amount of fill material, depth of jump pool below culvert, height of leap required to enter culvert, previous modifications (if any) to improve fish passage, and evaluate effectiveness of previous modifications. All site-specific data were entered into a spreadsheet for potential database uses.

3. Information regarding culvert age, wear, and performance was collected, including: overall condition of the pipe and rust line height. Presence or absence and condition of trash racks was also assessed. All culvert specifications were entered into a spreadsheet for potential database uses.

4. An evaluation of fish passage at each culvert location. Fish passage was evaluated by two methods. First, information collected on culvert specifications was used to calculate hydraulic characteristics of each culvert over a range of expected migration flows. These values were compared to values cited in current scientific literature regarding the leaping and swimming abilities of juvenile and adult coho salmon, steelhead, and chinook salmon. FishXing (a computer software program) modeled

culvert hydraulics over the range of migration flows and compared these values with leaping and swimming abilities of the species and lifestage of interest. Secondly, passage was assessed by on-site observations of fish movement during expected periods of migration; primarily during and after rain storms between the months of December and March.

5. Photo documentation of each culvert to provide visual information regarding inlet and outlet configurations. Site photographs were digitized and provided on CD's for easy insertion into future reports, proposals, or presentations

6. An evaluation of quantity and quality of fish habitat above and below each culvert location. Some information was obtained from habitat typing surveys previously conducted by CDFG, USFS, watershed groups, and/or timber companies. Where feasible, a first-hand inspection and evaluation of stream habitat occurred. Length of potential anadromous habitat was also estimated from USGS topographic maps. In situations where formal habitat typing surveys were not conducted and/or access to stream reaches was not permitted, professional judgment of biologists familiar with watershed conditions was utilized.

7. A ranked list of culverts that require treatment to provide unimpeded fish passage to spawning and rearing habitat. On a site-by-site basis, general recommendations for providing unimpeded fish passage were provided. For example, some stream crossings may require a bridge or properly-sized culvert set below stream grade to accommodate fish passage, whereas other locations may just require building up the outlet pool with rip rap to back-flood the culvert and/or baffles to reduce velocities within the culvert.

Project Justification

Fish passage through culverts is an important factor in the recovery of depleted salmonid populations throughout the Pacific Northwest. Although most fish-bearing streams with culverts tend to be relatively small in size with only a couple of miles or less of upstream habitat, thousands of these exist and the cumulative effect of blocked habitat is probably quite significant. Culverts often create temporal, partial or complete barriers for anadromous salmonids on their spawning migrations (Table 1)(adapted from Robison et al. 2000).

Typical passage problems created by culverts are:

- Excessive drop at outlet (too high of entry leap required);
- Excessive velocities within culvert;
- Lack of depth within culvert;
- Excessive velocity and/or turbulence at culvert inlet; and
- Debris accumulation at culvert inlet and/or within culvert.

Table 1. Definitions of barrier types and their potential impacts.

Barrier Category	Definition	Potential Impacts
Temporal	Impassable to all fish some of the time	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and life stages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning, or reductions in viability of eggs and offspring. Migrating fish concentrated in pools and stream reaches below road crossings are also more vulnerable to predation by a variety of avian and mammalian species, as well as poaching by humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in under-seeded headwaters and superimposition of redds in lower stream reaches.

Current guidelines for new culvert installation aim to provide unimpeded passage for both adult and juvenile salmonids (NMFS 2001). However many existing culverts on federal, state, county, and private roads are barriers to anadromous adults, and more so to resident and juvenile salmonids whose smaller sizes significantly limit their leaping and swimming abilities to negotiate culverts. For decades, "legacy" culverts on established roads have effectively disrupted the spawning and rearing behavior of all four species of anadromous salmonids in California: Chinook salmon, coho salmon, coastal rainbow trout (steelhead are anadromous coastal rainbow trout), and coastal cutthroat trout (*Oncorhynchus clarki clarki*).

In recent years, there has been a growing awareness of the disruption of in-stream migrations of resident and juvenile salmonids caused at road/stream intersections. In-stream movements of juvenile and resident salmonids are highly variable and still poorly understood by biologists. Juvenile coho salmon spend approximately one year in freshwater before migrating to the ocean, and juvenile steelhead may rear in freshwater for up to four years prior to out-migration (one to two years is most common in California). Thus, juveniles of both species are highly dependent on stream habitat.

Many studies indicate that a common strategy for over-wintering juvenile coho is to migrate out of larger river systems into smaller streams during late-fall and early-winter storms to seek refuge from possibly higher flows and potentially higher turbidity levels in mainstem channels (Skeesick 1970; Cederholm and Scarlett 1981; Tripp and McCart 1983; Tschaplinski and Hartman 1983; Scarlett and Cederholm 1984; Nickelson et al. 1992). Recent research conducted in coastal, northern California watersheds suggests that juvenile salmonids migrate into smaller tributaries in the fall and winter to feed on eggs deposited by spawning adults as well as flesh of spawned-out adults (Roelofs, pers. comm). Direct observation at numerous culverts in northern California confirmed similar upstream movements of three year-classes of juvenile steelhead (young-of-year, 1-year old and 2-year old) (Taylor 2000).

The variable life history of resident coastal rainbow trout is exhibited by seasonal movements in and out of one or more tributaries within a watershed. These smaller tributaries are where most culverts are still located since larger channels tend to be spanned by bridges.

In response to the 1994 federal listing of coho salmon as threatened in northern California, five counties (Humboldt, Del Norte, Trinity, Siskiyou, and Mendocino) formed the Five-Counties Salmon Group to examine various land-use activities conducted or permitted under county jurisdiction that may impact coho salmon habitat. Initial meetings identified causative factors of potential impacts, information gaps, and priority tasks required to obtain missing information. A high-priority task included conducting culvert inventories on county roads to evaluate fish passage and prioritize treatments.

Anadromous salmonids will benefit from this planning effort because the final document provides Siskiyou County's Department of Public Works with a prioritized list of culvert locations to fix that will provide unimpeded passage for all species (and life stages) of salmonids. Report information will assist in proposal development to seek State and Federal money to implement treatments. The inventory will also provide the County Public Works with a comprehensive status evaluation of the overall condition and sizing of culverts within fish-bearing stream reaches, providing vital information to assist the County's general planning and road's maintenance needs.

METHODS AND MATERIALS

Methods for conducting the culvert inventory and fish passage evaluation included eight tasks; accomplished generally in the following order:

1. Location of stream crossings.
2. Initial site visits and data collection.
3. Estimation of tributary-specific hydrology and design flows for presumed migration period.
4. Data entry and passage analyses. Passage was first evaluated with a first-phase evaluation filter referred to as the "Green-Gray-Red" filter. Sites determined to be "Gray" then required an in-depth evaluation with FishXing – a computer modeling software.
5. Site visits for migration observations during fall/winter migration flows.
6. Collection and interpretation of existing habitat information.
7. Prioritization of sites for corrective treatment.
8. Site-specific recommendations for unimpeded passage of both juvenile and adult salmonids.

Location of Culverts

Preliminary project scoping included examination of Siskiyou County road system maps and counting road/stream intersections on known (current and historic) anadromous stream reaches. The National Marine Fisheries Service (NMFS) coho salmon stock questionnaire list was used to identify and locate coho and steelhead streams on the Siskiyou County road maps. NMFS's list of current and historic coho streams was based heavily on a compilation of field and survey reports produced by Brown et al. (1994).

Eighty-seven county stream crossings were initially identified on anadromous stream reaches. Because the use of maps was considered a rough, first-cut at locating potential stream crossings, additional sites were also investigated once the project started. Most of these sites were identified by fisheries biologists, restoration/watershed groups, or county personnel with field-level knowledge regarding Siskiyou county streams and road networks (D. Howell; P. Brucker; J. Villeponteaux; D. Maria; pers. comm.).

Initial Site Visits

The objective of the initial site visits was to collect physical measurements at each crossing to utilize with the Green-Gray-Red evaluation filter and FishXing. Notes describing the type and condition of each culvert, as well as qualitative comments describing stream habitat immediately above and below each culvert were also included. Photographs of the outlet and inlet were taken at each site.

Culvert Location

The location of each culvert was described by: Siskiyou County road system map # ; road name and number; stream name; watershed name; name of USGS quad map; Township, Range, and Section; latitude and longitude; and mile marker or distance to nearest named cross-road. If more than one county road culvert crossed single stream, a number was assigned to the stream name with the #1 culvert located farthest downstream (numbering then proceeded in an upstream direction). Lat/long coordinates were determined using Terrain Navigator (Version 3.01 by MapTech), a geo-referenced mapping software program; or in the field with a handheld GPS unit. For data entry purposes, all lat/long coordinates were provided in the North American 1927 datum (NAD27).

Longitudinal Survey

A longitudinal survey was shot at each culvert to provide accurate elevation data for FishXing passage analyses. We utilized an auto-level (Topcon AT-G7) with an accuracy of ± 2.5 mm, a domed-head surveyor's tripod, and a 25' leveling rod in 1/100' increments. All data and information were written on water-proof data sheets with a pencil. Data sheets were photocopied to provide back-ups in case of loss or destruction of originals.

Once a site was located in the field by the two-person survey crew, bright orange safety cones with signs marked "Survey Party" were placed to warn oncoming traffic from both directions. Bright orange vests were also worn by the survey crew. Vests increased one's visibility to traffic, and decreased suspicions of nearby property owners to our unannounced presence in the roadside stream channel. If sites were close to private residences, we attempted to contact the property owners to inform them of our survey of the county-maintained stream crossing.

To start the survey, a 300-foot tape (in 1/10' increments) was placed down the approximate center of the stream channel. The tape was started on the upstream side of the culvert, usually in the riffle crest of the first pool or run habitat unit above the culvert. This pool or run was considered the first available resting habitat for fish negotiating the culvert. The tape was set to follow any major changes in channel direction. The tape was set through the culvert and continued downstream to at least the riffle crest (or control) of the pool immediately downstream of the culvert outlet. If several "stair-stepped" pools led up to the culvert inlet, then the tape was set to the riffle crest of the lower-most pool. Extreme caution was used when wading through culverts. A hardhat and flashlight were standard items used during the surveys.

The tripod and mounted auto-level were set in a location to eliminate or minimize the number of turning points required to complete the survey. If possible, a location on the road surface was optimal, allowing a complete survey to be shot from one location. The leveling rod was placed at the thalweg (deepest point of channel cross-section at any given point along the center tape) at various stations along the center tape, generally capturing visually noticeable breaks in slope along the stream channel.

At all sites, five required elevations were measured (Figure 1):

1. culvert inlet,
2. culvert outlet,
3. maximum pool depth within five feet of the outlet,
4. outlet pool control, and
5. active channel margin between the culvert outlet and the outlet pool control. An active channel discharge is less than a bankfull discharge and is often identified by several features, including (Figure 2):

- Edge of frequently scoured substrate.
- Break in rooted vegetation or moss growth on rocks along stream margins.
- Natural line impressed on the bank.
- Shelving.
- Changes in soil character.

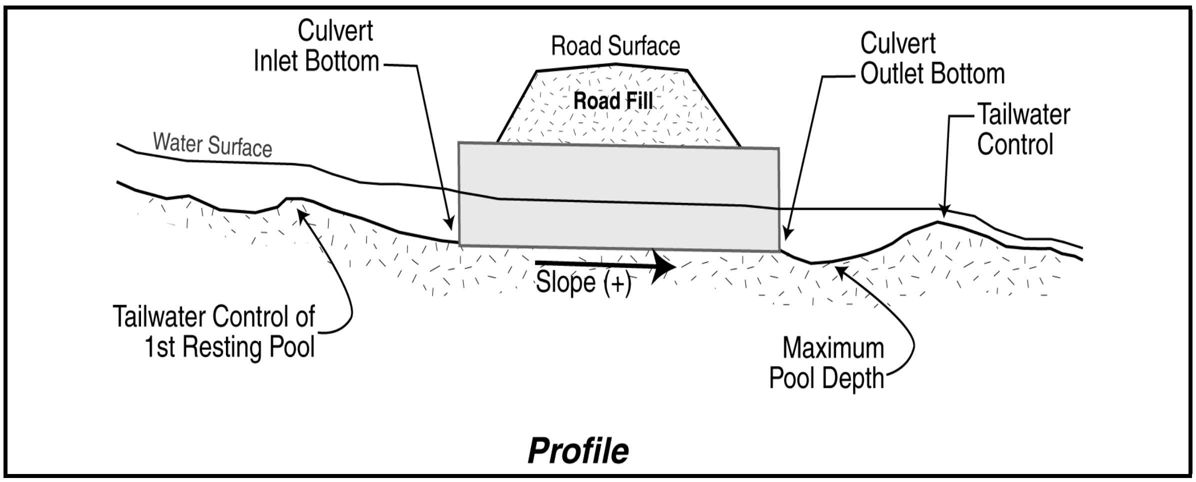


Figure 1. Diagram of required survey points though a culvert at a typical stream crossing.

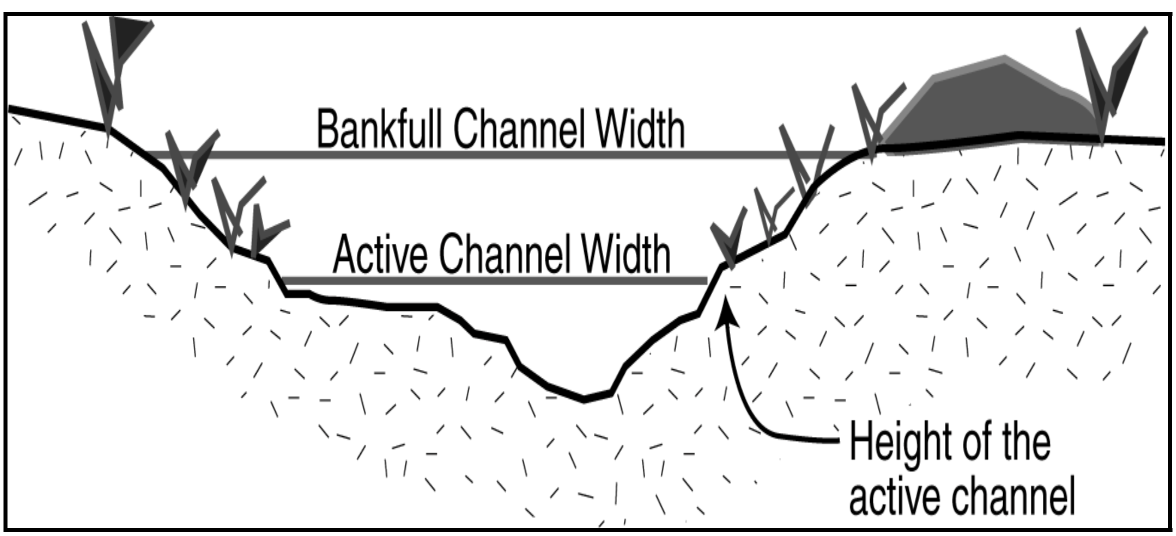


Figure 2. Active channel width versus bankfull channel width.

On a site-specific basis, the following additional survey points provided useful information for evaluating fish passage with FishXing:

- Apparent breaks-in-slope within the crossing. Older culverts often sag when road fills slump, creating steeper sections within a culvert. If only inlet and outlet elevations are measured, the overall slope will predict average velocities less than actual velocities within steeper sections. These breaks-in-slope may act as velocity barriers, which are masked if only the overall slope of the culvert is measured. The tripod and auto-level were set within the culvert or channel to measure breaks-in-slope.

- Steep drops in the stream channel profile immediately upstream of the culvert inlet. Measure the elevation at the tail of the first upstream holding water (where the tape was set) to estimate the channel slope leading into the culvert. In some cases, a fish may negotiate the culvert only to fail at passing through a velocity chute upstream of the inlet entrance. Inlet drops often create highly turbulent conditions during elevated flows.

All elevations were measured to the nearest 1/100' and entered with a corresponding station location (distance along center tape) to the nearest 1/10'.

Channel widths

Where feasible, at least five measurements of the active channel width above the culvert (visually beyond any influence the crossing may have on channel width) were taken. Active channel is defined as the portion of channel commonly wetted during and above winter base flows and is identified by a break in rooted vegetation or moss growth on rocks along stream margins. Some culvert design guidelines utilize active channel widths in determining the appropriate widths of new culvert installations (NMFS 2001; CDFG 2001; Robison et al 2000; Bates et al. 1999).

Although not required, in many cases a cross-section survey of at least the bankfull channel width at the outlet pool control was measured to increase the accuracy of passage analyses. For more detail, refer to the extensive "Help files" provided with FishXing (Love 2000).

Fill Estimate:

At each culvert, the volume of road fill placed above the stream channel is estimated from field measurements Fill volume estimates are incorporated into the ranking of sites for treatment and can assist in:

1. Calculating culvert flood capacity at HW/Fill =1 (water surface at top of fill prism).
2. Determining potential volume of sediment delivered to downstream habitat if the stream crossing fails.

3. Developing rough cost estimates for barrier removal by estimating equipment time required for fill removal and disposal site space needed.

Road fill volume is estimated using procedures outlined in Flannigan et al. (1998). The following measurements are taken to calculate the fill volume (Figure 3):

1. Upstream and downstream fill slope lengths (L_d and L_u).
2. Slope (%) of upstream and downstream fill slopes (S_d and S_u).
3. Width of road prism (W_r).
4. Top fill width (W_f).
5. Base fill width (W_c).

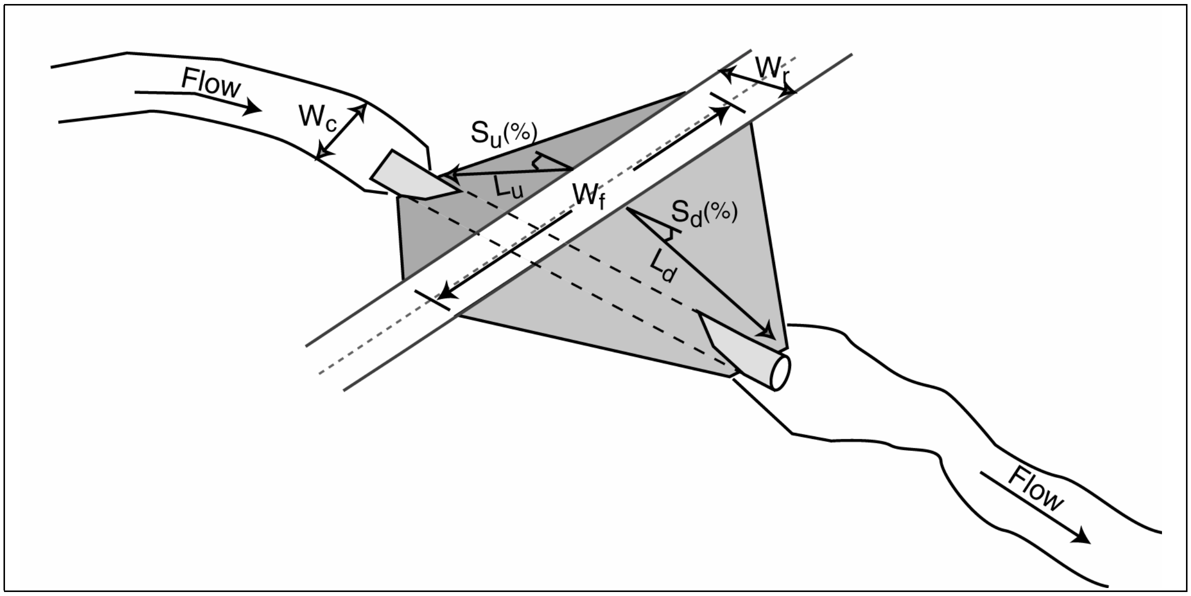


Figure 3. Road fill measurements.

Equations (1) through (4) to were used calculate the fill volume.

(1) Upstream prism volume, V_u:

$$V_u = 0.25(W_f + W_c)(L_u \cos S_u)(L_u \sin S_u)$$

(2) Downstream prism volume, V_d:

$$V_d = 0.25(W_f + W_c)(L_d \cos S_d)(L_d \sin S_d)$$

(3) Volume below road surface, V_r:

$V_r = 0.25(H_u + H_d)(W_f + W_c) W_r$

where: $H_u = L_u \sin S_u$, and

$H_d = L_d \sin S_d$

(4) Total fill volume, *V*:

$V = V_u + V_d + V_r$

NOTE: The fill measurements used as part of this inventory protocol were meant to generate rough volumes for comparison between sites while minimizing the amount of time required to collect the information. These volume estimates can contain significant error and should not be used for designing replacement structures.

<u>Other Site-specific Measurements</u>

For each site, the following culvert specifications were collected:

1. Length (to nearest 1/10 of foot);
2. Dimensions: diameter (circular), or height and width (box culverts), or span and rise (pipe arches);
3. Type: corrugated metal pipe (CSP), structural steel plate (SSP), concrete pipe, concrete box, bottomless pipe arch, squashed pipe-arch, or a composite of materials;
4. Overall condition of pipe (good, fair, poor, extremely poor);
5. Height and width of the rust line (if present);
6. Position relative to flow and stream gradient;
7. Depth of jump pool below culvert;
8. Height of jump required to enter culvert;
9. Previous modifications (if any) to improve fish passage; and
10. Condition of previous modifications.

Qualitative notes describing stream habitat immediately upstream and downstream of each culvert were taken. Where feasible, variable lengths of the stream channel above and below crossings were walked to detect presence of salmonids and provide additional information regarding habitat conditions.

Data Entry and Passage Analyses

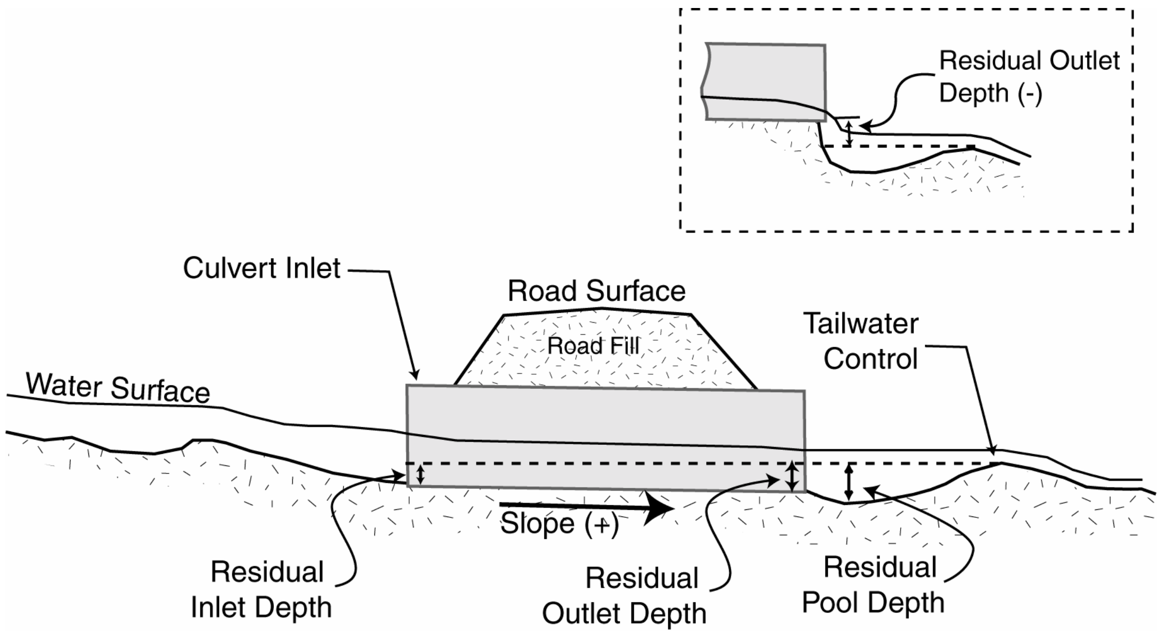
All survey and site visit data were recorded on waterproof data sheets. Then data for each culvert were entered into a spreadsheet (Excel 97). A macro was created to calculate thalweg elevations of longitudinal profiles and compute culvert slopes.

First-phase Passage Evaluation Filter: Green-Gray-Red

A filtering process was used to assist in identifying sites which either meet, or fail to meet, state and federal fish passage criteria for all fish species and lifestages (CDFG 2001; NMFS 2001). Using the field inventory data, calculate: average active channel width, culvert slope, residual inlet depth and drop at outlet (Figure 4). The first-phase passage evaluation filter was employed to reduce the number of crossings which require an in-depth passage evaluation with FishXing. The filter criteria were designed to quickly classify crossings into one of three categories:

- **GREEN**: Conditions assumed adequate for passage of all salmonids, including the weakest swimming lifestage.
- **GRAY**: Conditions may not be adequate for all salmonid species or lifestages presumed present. Additional analyses required to determine extent of barrier for each species and lifestage.
- **RED**: Conditions do not meet passage criteria at all flows for strongest swimming species presumed present. Assume "no passage" and move to analysis of habitat quantity and quality upstream of the barrier.

Follow the flowchart to determine a stream crossing's status as Green, Gray, or Red (Figure 5). Depending on geographic location within California, species of interest will vary. Within anadromous-bearing watersheds, CDFG has determined that culverts classified as "Green" must meet upstream passage criteria for both adult and over-wintering juvenile salmonids at all expected migration flows.



Residual Pool Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Pool Bottom}})$

Outlet Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Culvert Outlet}})$ *(No outlet drop if Outlet Depth ≥ 0)*

Residual Inlet Depth = $(\text{Elev}_{\text{Tailwater Control}} - \text{Elev}_{\text{Culvert Inlet}})$

Figure 4. Measurements used in Green-Grey-Red filtering criteria.

Many stream crossings have unique characteristics which may hinder fish passage, yet they are not recognized in the filtering process. For culverts meeting the "Green" criteria, a review of the inventory data and field notes was necessary to ensure no unique passage problems exist before classifying the stream crossings as "100% passable".

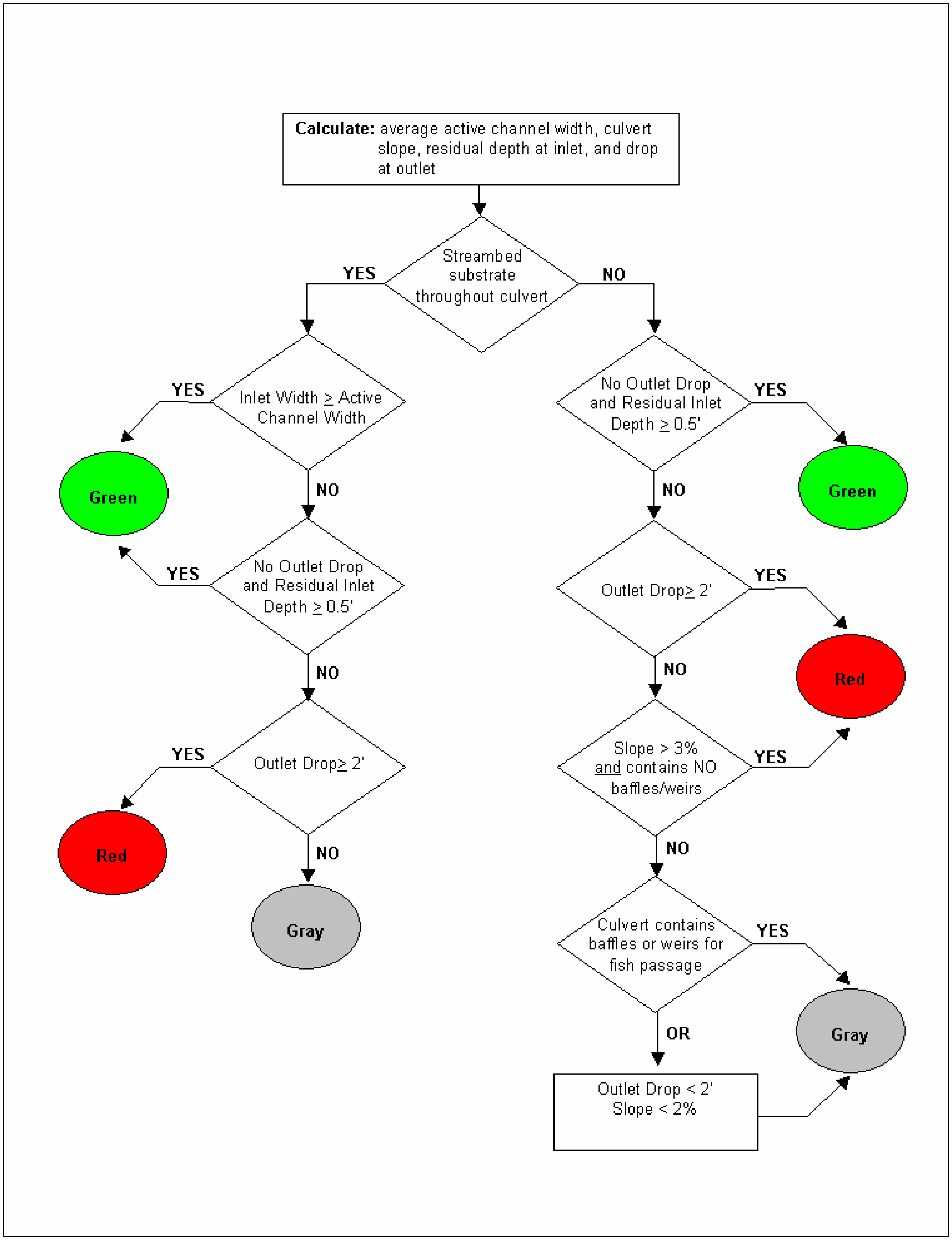


Figure 5. Green-Gray-Red first-phase passage evaluation filter.

NOTE: FishXing Overview, Hydrology and Design Flow, Peak Flow Capacity, and Fish Passage Flows sections were written by Michael Love and Associates under a separate contract administered by CDFG (Taylor and Love, in press).

FishXing Overview

FishXing is a computer software program developed by Six Rivers National Forest's Watershed Interactions Team - a group of scientists with diverse backgrounds in engineering, hydrology, geomorphology, geology and fisheries biology. In-depth information regarding FishXing (or a copy) may be obtained at the Fish Crossing homepage on the internet (www.stream.fs.fed.us/fishxing/).

FishXing is an interactive software package that integrates a culvert design and assessment model for fish passage nested within a multimedia educational setting. Culvert hydraulics are well understood and model output closely resembles reality. FishXing successfully models (predicts) hydraulic conditions throughout the culvert over a wide range of flows for numerous culvert shapes and sizes. The model incorporates fisheries inputs including fish species, life stages, body lengths, and leaping and swimming abilities. FishXing uses the swimming abilities to determine whether the culvert installation (current or proposed) will accommodate fish passage over a desired range of migration flows, and identify specific flows and locations within the culvert that impede or prevent passage. Software outputs include water surface profiles and hydraulic variables such as water depths and average velocities displayed in both tabular and graphical formats.

FishXing used the survey elevation and culvert specifications to evaluate passage at sites defined as "Grey" by the first-phase evaluation filter for each species and life stage of salmonids known to currently or historically reside in the Siskiyou County streams of interest. The swimming abilities and passage criteria used for each species and lifestage are listed Table 2. Although many individual fish will have swimming abilities surpassing those listed below, swim speeds were selected to ensure stream crossings accommodate passage of weaker individuals within each age class.

FishXing and other hydraulic models report the average cross-sectional water velocity, not accounting for spatial variations. Stream crossings with natural substrate or corrugations will have regions of reduced velocities that can be utilized by migrating fish. These areas are often too small for larger fish to use, but can enhance juvenile passage success. The software allows the use of reduction factors that decrease the calculated water velocities proportionally. As shown in Table 2, velocity reduction factors were used in the passage analysis of two groups of age classes: resident fish/age 2+ juveniles and age 1+/young-of-year juveniles with specific types of stream crossing structures.

Using the FishXing program, the range of flows that meet the depth, velocity, and leaping criteria for each life stage were identified. The range of flows meeting the passage requirements were then compared to the lower and upper fish passage flows to determine "percent passable".

Table 2. Fish passage criteria used in the analysis, listed by species and life-stage. Although many individual fish will have swimming abilities surpassing those listed below, swim speeds were selected to ensure road-stream crossings accommodate passage of weaker individuals within each class. Values for the velocity reduction factors, which account for regions of lower velocity found along the culvert walls, were taken from Behlke (1991) Passage flows are based on existing draft guidelines provided by the Department of Fish and Game (CDFG, 2001).

Fish Species/Age Class	**Adult Steelhead and Coho**	**Resident Trout**	**Juvenile Salmonids**
Fish Length	500 mm	200 mm	80 mm
Prolonged Mode			
Swim Speed	6.0 ft/s	2.5 ft/s	1.5 ft/s
Time to Exhaustion	30 min	30 min	30 min
Burst Mode			
Swim Speed	10.0 ft/s	5.0 ft/s	3.0 ft/s
Time to Exhaustion	5 s	5 s	5 s
Maximum Leaping Speed	12.0 ft/s	6.0ft/s	4.0 ft/s
Velocity Reduction Factors for Corrugated Metal Culverts [1]	Inlet = 1.0 Barrel = 1.0 Outlet = 1.0	Inlet = 0.8 Barrel = 0.6 Outlet = 0.8	Inlet = 0.8 Barrel = 0.6 Outlet = 0.8
Minimum Required Water Depth	0.8 ft	0.5 ft	0.3 ft
Minimum Passage Flow *(Use the larger of the two flows)*	50% exceedance flow or 3 cfs	90% exceedance flow or 2 cfs	95% exceedance flow or 1 cfs
Maximum Passage Flow	1% exceedance flow	5% exceedance flow	10% exceedance flow

[1] Velocity reduction factors only apply to culverts with corrugated walls, baffles, or natural substrate. All other culverts had reduction factors of 1.0 for all fish.

Hydrology and Design Flow

When examining stream crossings that require fish passage, three specific flows are considered: peak flow capacity of the stream crossing, the upper fish passage flow, and the lower fish passage flow. Because flow is not gaged on most small streams, it must be estimated using techniques that required hydrologic information about the stream crossing's contributing watershed, including:

- Drainage area;
- Mean annual precipitation;
- Mean annual potential evapotranspiration; and

Drainage area was calculated from a 1:24,000 USGS topographic map. Mean annual precipitation (MAP) was estimated using the *Siskiyou County Drainage Manual* prepared by Raymond Vail and Associates for the County Department of Public Works. Potential evapotranspiration (PET) was estimated from regional maps produced by Rantz (1968).

Peak Flow Capacity

Peak flows are typically defined in terms of a recurrence interval, but reported as a quantity; often as cubic feet per second (cfs). Current guidelines recommend all stream crossings pass the flow associated with the 100-year flood without damage to the stream crossing (NMFS, 2001). Additionally, culverts on streams with high woody debris loads should accommodate the 100-year flood without overtopping the culvert's inlet.

Determination of a crossing's flood capacity assisted in ranking sites for remediation. Undersized crossings have a higher risk of catastrophic failure, which often results in the immediate delivery of sediment from the road- fill into the downstream channel. Undersized crossings can also adversely effect sediment transport and downstream channel stability, creating conditions that hinder fish passage, degrade habitat, and may cause damage to other stream crossings and/or private property.

The first step was to estimate hydraulic capacity of each inventoried stream crossing. Capacity is generally a function of the shape and cross-sectional area of the inlet. Capacity was calculated for two different headwater elevations: water ponded to the top of the culvert inlet (HW/D = 1) and water ponded to the top of the road surface (HW/F=1). Nomograph equations developed by Piehl et. al (1988) were used to calculate capacities of circular culverts. Federal Highways nomographs presented in Norman et.al (1995) were used for pipe-arches and box culverts. For embedded culverts, the crossing was assumed to be outlet controlled and hydraulic capacity was determined using the FishXing software. All other culverts were assumed to be inlet controlled at $HW/D \geq 1$.

The second step was to estimate peak flows at each crossing. This required estimating the 5-year, 10-year, 25-year, 50-year, and 100-year peak flows. Local flood estimation charts presented in the *Siskiyou County Drainage Manual* were used to estimate peak flows for the various recurrence intervals. The manual separates Siskiyou County into two distinct hydrologic regions and 27 sub-regions. Variables influencing peak flows within each sub-region were drainage area and mean annual precipitation.

The third step was to compare the stream crossing capacity to peak flow estimates. Risk of failure was assessed by comparing a stream crossing's hydraulic capacity with the estimated peak flow for each recurrence interval. Each crossing was placed into one of six "sizing" categories for capacity at HW/D = 1:

1. equal to or greater than the 100-year flow,
2. between the 50-year and 100-year flows,
3. between the 25-year and 50-year flows,
4. between the 10-year and 25-year flows,
5. between the 10-year and 5-year flows.
6. less than the 5-year storm flow.

These six categories were utilized in the ranking matrix.

Details pertaining to the hydraulic capacity and estimated peak flows for each stream crossing are listed in Appendix C.

<u>Fish Passage Flows</u>

It is widely agreed that designing stream crossings to pass fish at all flows is impractical (CDFG; NMFS 2001; Robison et al. 2000; SSHEAR 1998). Although anadromous salmonids typically migrate upstream during higher flows triggered by hydrologic events, it is presumed that migration is naturally delayed during larger flood events. Conversely, during low flow periods on many smaller streams, water depths within the natural channel can become impassable for both adult and juvenile salmonids. To identify the range of flows that stream crossings should accommodate fish passage, lower and upper flow limits have been defined specifically for streams within California (CDFG 2001; NMFS 2001).

Prescribed lower and upper fish passage flow criteria for adult anadromous salmonids, resident trout, and juvenile salmonids are listed in Table 2. Between the lower and upper passage flows stream crossings should allow unimpeded passage of all fish. These flow criteria were used to develop specific fish passage flows for each inventoried stream crossing.

To evaluate the extent to which a crossing is a barrier, passage conditions was assessed between the lower and upper passage flows for each salmonid lifestage of concern. Identifying the 1% and 50% exceedence flows required obtaining average daily stream flow data from nearby gaged basins. Daily average flow data for streams in Siskiyou County were available from the USGS.

The following steps were followed to estimate upper and lower passage flows:

1. Obtained flow records from local stream gages that met the following requirements:
   - At least 5-years of recorded daily average flows (do not need to be consecutive years);
   - A drainage area less than 100 square miles, and preferably less than 20 square miles; and,
   - Unregulated flows (no upstream impoundments or water diversions) during the migration season.

2. Divided the flows (Q) for each gaged stream by its drainage area (A), resulting in units of cfs/mi^2.

3. Grouped gaged streams by hydrologic sub-region, and lumped sub-regions together that produced similar flow duration curves.

4. Created a regional flow duration curves by taking the median of the exceedence flows (Q/A) of the gaged streams (Appendix C).

5. Determined the upper and lower passage flows for each stream crossing using the regional flow duration curve and the drainage area of the stream crossing.

When analyzing fish passage with FishXing, these flows were used to determine the extent to which the crossing is a barrier. The stream crossing must meet water velocity and depth criteria between Q_{lp} and Q_{hp} to be considered 100% passable (NMFS 2000). For the ranking matrix, at each road crossing, the extent of the migration barrier was determined for each salmonid species and lifestage presumed present.

Site Visits for Fish Migration Observations

During late-fall and winter storms, some sites were visited in order to observe salmonids attempting to migrate through culverts. These visits were limited to culverts with perched outlets because turbid conditions of most streams during winter migration flows allowed only observation of jump attempts.

The purpose of these visits was to:
1. Confirm upstream migration of adult and/or juvenile salmonids.
2. Record numbers of successful and failed attempts at specific culverts.
3. Observe behavior of jump attempts.
4. Identify locations with high levels of migration.
5. Better understand the timing of fish migration as related to storm hydrographs.
6. Measure velocities through culverts and jump heights during migration flows.

Migration observation data were not intended for use in the ranking matrix for several reasons:
1. observations were made at a subset of culvert locations;

2. observations were conducted sporadically at various locations and flow levels; and
3. total observation time (in minutes) accounted for a small fraction of total migration period.

However, this information provided valuable insight of fish behavior at culverts and served as an important component of professional judgment in the final ranking of priority locations. The protocol used for conducting observations at perched culverts is located in Appendix E.

Habitat Information

Because this project addressed fish passage in many tributaries within the Klamath River watershed, plan development was based both on prior assessment and evaluation; and on conducting habitat assessment and evaluation as part of the project. Habitat conditions upstream and downstream of culvert locations relied on previously conducted habitat typing or fisheries surveys. Habitat information and fish distribution data were used from reports on file at CDFG and USFS offices in Yreka and Fort Jones. These surveys also provided information on past, present, and future land uses within watersheds that flow through culverts on the Siskiyou County road system. Notes generated from surveys on file with CDFG and USFS are included in Appendix F.

Professional judgment from on-site inspection of culverts and stream habitat also aided habitat assessment and evaluation. In some cases, with landowner permission, longer reaches of stream were walked to better assess quality of habitat above and below county culverts. These surveys also aided in the examination of several road crossings on private roads.

Length of potential salmonid habitat upstream of each county culvert was estimated off of digitized USGS 7.5 Minute Series topographic maps (Terrain Navigator, Version 3.01 by MapTech). The upper limit of anadromous habitat was considered when the channel exceeded an eight percent slope. Because steep elevational changes at local features such as cascades or waterfalls are often not captured on USGS topographic maps, previously conducted surveys aided in better identifying the upper limits of anadromy in some streams.

The presence of additional road crossings, above and below each county-maintained site, was also considered when evaluating potential habitat gains. In many cases, additional road crossings existed, either private-maintained, federal (USFS) or state (CALTRANS). These crossings were not evaluated in detail (with FishXing), but were examined for visual estimates of length, slope, and presence of perched outlets.

Initial Ranking of Stream Crossings for Treatment

The need for extensive habitat information collected in a consistent manner is time consuming and expensive to generate. Detailed information was not available for many Siskiyou County watersheds and conducting surveys was beyond the scope (and budget) of this project. The ranking objective was to arrange the sites in an order from high to low priority using a suite of site-specific information. However, the "scores" generated were not intended to be absolute in deciding the exact order of scheduling treatments. Once the first-cut ranking was completed, professional judgment played an important part in deciding the order of treatment. As noted by Robison et al. (2000), numerous social and economic factors influenced the exact order of treated sites.

Because Siskiyou County intends on treating culvert sites identified as "high-priority" by submitting proposals to various fisheries restoration funding sources, additional opportunities for re-evaluating the biological merit of potential projects will occur through proposal review committees composed of biologists from CDFG and other agencies. The methods for ranking culvert locations is a developing process and will undoubtedly require refinement as additional information is obtained. This report also acknowledges (but makes no attempt to quantify or prioritize) that other potentially high-priority restoration projects exist throughout California, and these must <u>all</u> be considered when deciding where and how to best spend limited restoration funds.

<u>Ranking Criteria</u>

The criteria and scoring for ranking stream crossings were consistent with those developed for Part 10 of CDFG's *Salmonid Stream Habitat Restoration Manual* (Taylor and Love, in press). The method assigns a score or value for the following criteria at each culvert location. The total score is the sum of five criteria: species diversity, extent of barrier, sizing, current condition, and total habitat score.

1. **Species diversity:** number of salmonid species known to occur (or historically occurred) within the stream reach at the culvert location. **Score:** Because of ESA listing status as threatened coho salmon = **2** points; and non-listing status of chinook salmon and steelhead = **1** point for each species. Maximum possible score for Siskiyou County = **4 points (coho = 2; chinook = 1; steelhead = 2).**

2. **Extent of barrier:** for each life stage (adults, resident/two-years olds, and juveniles) expected to occur, over the range of estimated migration flows, assign one of the following values. **Score: 0** = 80-100% passable; **1** = 60-80% passable; **2** = 40-60% passable; **3** = 20-40% passable; **4** = less than 20% passable; **5** = 0% passable (**RED** by first-phase evaluation filter). For a total score, sum scores given for adult species and each year-class of juveniles. Maximum possible score = **15 points.**

3. **Sizing (risk of failure):** for each culvert, assign one of the following values as related to flow capacity. **Score: 0 =** sized to NMFS standards of passing 100-year

flow at less than inlet height. **1** = sized for at least a 50-year flow, low risk. **2** = sized for at least a 25-year flow, moderate risk.. **3** = sized for less than a 25-year flow, moderate to high risk of failure. **4** = sized for less than a 10-year event, high risk of failure. **5** = sized for less than a five-year event, high risk of failure.

4. **Current condition:** for each culvert, assign one of the following values. **Score:** **0** = good condition. **1** = fair, showing signs of wear. **3** = poor, floor rusting through, crushed by roadbase, etc. **5** = extremely poor, floor rotted-out, severely crushed, damaged inlets, collapsing wingwalls, slumping roadbase, etc.

5. **Habitat quantity:** above each crossing, length in feet to sustained 8% gradient. **Score:** Starting at a 500' minimum; 0.1 points for each 100' length class (**example**: **0** points for <500'; **1** point for 1,000'; **2** points for 2,000'; **3.5** points for 3,500'; **4.7** points for 4,700'; and so on). NOTE: maximum score for quantity = **10 points.**

6. **Habitat quality:** for each stream, assign a "multiplier" of quality (relative to other streams in inventory) after reviewing available habitat information.

- **Score: 1.0 = Excellent-** Relatively undeveloped, "pristine" watershed conditions. Habitat features include dense riparian zones with mix of mature native species, frequent pools, high-quality spawning areas, cool summer water temperatures, complex in-channel habitat, channel floodplain relatively intact. High likelihood of no future human development. Presence of migration barrier(s) is obviously the watershed's limiting factor.

- **0.75 = Good-** Habitat is fairly intact, but human activities have altered the watershed with likelihood of continued activities. Habitat still includes dense riparian zones of native species, frequent pools, spawning gravels, cool summer water temperatures, complex in-channel habitat, channel floodplain relatively intact. Presence of migration barrier(s) is most likely one of the watershed's primary limiting factor.
- **0.5 = Fair-** Human activities have altered the watershed with likelihood of continued (or increased) activities, with apparent effects to watershed processes and features. Habitat impacts include riparian zone present but lack of mature conifers and/or presence of non-native species, infrequent pools, sedimentation evident in spawning areas (pool tails and riffle crests), summer water temperatures periodically exceed stressful levels for salmonids, sparse in-channel complex habitat, floodplain intact or slightly modified). Presence of migration barrier(s) may be one of the watershed's limiting factor (out of several factors).

- **0.25 = Poor-** Human activities have drastically altered the watershed with high likelihood of continued (or increased) activities, with apparent effects to watershed processes. Habitat impacts include riparian zones absent or severely degraded, little or no pool formations, excessive sedimentation evident in spawning areas (pool tails and riffle crests), stressful to lethal summer water temperatures common, lack of in-channel habitat, floodplain severely modified with levees, riprap, and/or residential or commercial development. Other limiting factors within watershed are most likely of a higher priority for restoration than remediation of migration barriers.

7. **Total habitat score:** Multiply #5 by #6 for habitat "score". A multiplier assigned for habitat quality, weighs the final score more on quality than sheer quantity of upstream habitat. Maximum possible score = **10 points.**

For each culvert location, the five ranking criteria were entered into a spreadsheet and total scores computed. Then the list was sorted by "Total Score" in a descending order to determine an initial ranking. On closer review of the rank, some professional judgment was used to slightly adjust the rank of several sites. The list was then divided subjectively into groups defined as "high", "medium", or "low" priority.

The high-priority sites were generally characterized as complete migration barriers with significant amounts of upstream habitat for at least two species of anadromous salmonids. Many of these sites were also undersized and/or in poor condition. Medium-priority sites were characterized by one or more of the following factors: limited in upstream habitat gains, extensive reaches of poor-quality habitat; limited species diversity, and/or were temporal or partial migration barriers. Low-priority sites were either limited in upstream habitat, habitat condition was poor, and/or the site allowed passage of adults and most juveniles.

Remediation of culvert sites identified as "high-priority" should be accomplished by submitting proposals to various fisheries restoration funding sources. The information provided in this report should be used to document the logical process employed to identify, evaluate, and rank these migration barriers.

Siskiyou County Public Works should consider ranking medium and low-priority sites a second time, focusing mainly on culvert condition, sizing, and amount of fill material within the road prism. A risk assessment may be conducted to determine the consequence of potential sediment delivery to the downstream channel if or when a crossing failed. Most medium and low-priority sites should not be considered candidates for treatment via limited restoration funding sources, unless an imminent site failure would deliver a significant amount of sediment to downstream salmonid habitat.

However, this information will provide Siskiyou County Public Works a list of sites in need of future replacement with county road maintenance funds. When these replacements are implemented, this report should provide guidance on treatments with properly-sized crossings conducive to adequate flow conveyance and unimpeded fish passage.

RESULTS

Initial Site Visits

Initial site visits were conducted at a total of 118 road crossings in Siskiyou County (Table 3). However, only **36** of 118 crossings were surveyed. The reasons for excluding 82 sites in the evaluation varied and are listed in the right-hand column of Table 3. Most site visits and surveys were conducted during fall or spring low flows, which provided safer wading conditions in streams and through culverts.

The 36 surveyed sites were each given a unique ID number that was determined in an upstream direction starting at the Humboldt/Siskiyou County line and moving in generally a west to east direction (Table 4). A table of the 36 culvert sites inventoried and their location and site-specific characteristics information is provided in Appendix A.

Site-specific characteristics, passage evaluation results, site photographs, maps, and habitat descriptions for each of the 36 sites are provided in a “Catalog of Siskiyou County Culverts” (Appendix B). The following list is an overview of the culvert inventory:

1. A wide variety of culvert configurations and materials were discovered.

2. Many culverts were in poor condition (seven sites or 19.4%) and are due for replacement. Another 12 culverts (33.3%) were described as in “fair” condition, and starting to show signs of deterioration.

3. Most culverts were undersized when compared to recently released NMFS guidelines that recommend stream crossings pass the 100-year storm flow at less than 100% of inlet height. Only four sites (Merrill Creek/Salmon River Road, Sixmile Creek/Cecilville Road, Trail Creek/Cecilville Road, and Cronan Gulch/Sawyer’s Bar Road) were sized to pass more than a 100-year storm discharge. This is mostly likely because many county road crossings were constructed prior to the development of these extremely conservative guidelines. Another three crossings were sized relatively close to the NMFS guidelines: Vesa Creek/Klamath River Road (58-years); Williams Creek/Klamathon Road (53-years); Little Bogus Creek/Desevado Road 47-years). Five more culverts were moderately undersized and passed between a 10–year to 20-year storm flow at 100% of inlet capacity: Walker Gulch/Ladd Road (20-years); Kelly Gulch/Sawyer’s Bar Road (14-years); Robinson Gulch/Sawyer’s Bar Road); Cape Horn Creek/Copco Road (13-years); and Luther Gulch/Indian Creek Road.

   Nineteen of the 36 (or 53%) culverts were extremely undersized, overtopping on less than a ten-year storm flow – of these 19 sites, 10 (or 27.7%) were at 100% of inlet capacity on less than a five-year storm flow (Table 4). Undersized culverts tend to create migration barriers from excessive velocities caused by the channel restriction or/and from extremely perched outlets caused by hydraulic scouring of the downstream channel by water exiting the culvert <u>and</u> retention of bed load on the upstream side.

Table 3. List of 118 stream-crossing locations visited in Siskiyou County.

BASIN NAME	STREAM NAME	ROAD NAME	SURVEY STATUS
KLAMATH TRIBUTARIES			
	Ti Creek	Ukonom Lookout Road	Not County maintained
	Ottley Gulch	China Grade Road	**SURVEYED**
	Frying Pan Creek	China Grade Road	**SURVEYED**
	Horse Creek	China Grade Road	**SURVEYED**
	China Creek	China Grade Road	No, bridge
	Walker Gulch	Ladd Road	**SURVEYED**
	Schutt's Gulch	Ladd Road	Too steep
	McKinney Creek #1	Walker Road	**SURVEYED**
	McKinney Creek #2	McKinney Creek Road	Not County maintained
	McKinney Creek #3	McKinney Creek Road	Not County maintained
	Dona Creek	Walker Road	**SURVEYED**
	Collins Creek	Walker Road	**SURVEYED**
	Little Humbug Creek	Walker Road	**SURVEYED**
	Vesa Creek	Klamath River Road	**SURVEYED**
	China Gulch	Klamath River Road	Not fish-bearing
	Badger Creek	Klamath River Road	Not fish-bearing
	Ash Creek	Ash Creek Road	Not County maintained
	Williams Creek	Klamathon Road	**SURVEYED**
	Cape Horn Creek #1	Copco Road	**SURVEYED**
	Cape Horn Creek #2	Dry Creek Road	Not fish-bearing
	Little Bogus Creek #1	Desevado Road	**SURVEYED**
	Little Bogus Creek #2	Ager-Beswick Road	Not fish-bearing
Beaver Creek	Fish Gulch Creek	Beaver Creek Road	**SURVEYED**
	Dutch Creek	Beaver Creek Road	Not County maintained
	North Fork Hungry Ck.	Beaver Creek Road	Not County maintained
Cottonwood Creek	Rancheria Gulch #1	Oregon Road	Not fish-bearing
	Rancheria Gulch #2	Hornbrook Road	Not fish-bearing
	Rocky Gulch #1	Hornbrook Road	Not fish-bearing
	Rocky Gulch #2	Main Street	Not fish-bearing
	Rocky Gulch #3	Copco Road	Not fish-bearing
	Rocky Gulch #4	Rancheria Creek Road	Not fish-bearing
	Rocky Gulch #5	Main Street	Not fish-bearing
Elk Creek	Twin Creeks #1	Elk Creek Road	Not County maintained
	Twin Creeks #2	Elk Creek Road	Not County maintained
Grider Creek	Salt Creek	Grider Creek Road	Not County maintained
Humbug Creek	Humbug Creek	Hawkinsville-Humbug Creek Road	No, Bridge
	Clear Creek	Humbug Creek Road	**SURVEYED**
	South Fork Humbug Ck.	Yreka-Walker Road	**SURVEYED**
	Middle Fk. Humbug Ck.	Yreka-Walker Road	**SURVEYED**
	Kennebuc Gulch	Humbug Creek Road	Not fish-bearing
	Tincup Gulch	Humbug Creek Road	Not fish-bearing
	School House Gulch	Humbug Creek Road	Not fish-bearing

Table 3 (continued). List of 118 stream-crossing locations visited in Siskiyou County.

BASIN NAME	**STREAM NAME**	**ROAD NAME**	**SURVEY STATUS**
Indian Creek	Luther Gulch	Indian Creek Road	**SURVEYED**
	Slater Creek	Indian Creek Road	**SURVEYED**
	Baker Creek	Indian Creek Road	Not fish-bearing
Seiad Creek	Canyon Creek	Seiad Creek Road	Access denied by Jones family
	Darkey Creek	Seiad Creek Road	**SURVEYED**
SALMON RIVER			
	Merrill Creek	Salmon River Road	**SURVEYED**
	Grant Creek	Salmon River Road	Not fish-bearing
	Lewis Creek	Salmon River Road	Not fish-bearing
	Boyd Gulch	Salmon River Road	Not fish-bearing
	Dead Mule Gulch	Salmon River Road	Not fish-bearing
South Fork Salmon River			
	Hotelling Gulch	Callahan-Cecilville Rd.	**SURVEYED**
	Graham Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Butcher Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Limestone Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Orton Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Gibson Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Long Gulch	Callahan-Cecilville Rd.	Not fish-bearing
	Cecil Gulch	Callahan-Cecilville Rd.	Not county maintained
	Black Gulch	Callahan-Cecilville Rd.	Not county maintained
	Gibson Gulch	Caribou Road	Not fish-bearing
	Long Gulch	Caribou Road	Not fish-bearing
East Fork of the South Fork Salmon River			
	Sixmile Creek	Callahan-Cecilville Rd.	**SURVEYED**
	Trail Creek	Callahan-Cecilville Rd.	**SURVEYED**
North Fork Salmon River			
	Pollack Gulch	Sawyer’s Bar Road	Not fish-bearing
	Murder’s Gulch	Sawyer’s Bar Road	Not fish-bearing
	China Gulch	Sawyer’s Bar Road	Not fish-bearing
	Big Creek	Sawyer’s Bar Road	Not fish-bearing
	Olson Creek	Sawyer’s Bar Road	Not fish-bearing
	Boulder Creek	Sawyer’s Bar Road	Not fish-bearing
	Cronan Gulch	Sawyer’s Bar Road	**SURVEYED**
	Kelly Gulch	Sawyer’s Bar Road	**SURVEYED**
	Jackass Gulch	Sawyer’s Bar Road	No, bridge
	Crooks Gulch	Sawyer’s Bar Road	Not fish-bearing
	Tanner Gulch	Sawyer’s Bar Road	Not fish-bearing
	Rattlesnake Gulch	Sawyer’s Bar Road	Not fish-bearing
	White’s Gulch	White’s Gulch Road	**SURVEYED**
	Robinson Gulch	Sawyer’s Bar Road	**SURVEYED**

Table 3 (continued). List of 118 stream-crossing locations visited in Siskiyou County.

BASIN NAME	STREAM NAME	ROAD NAME	SURVEY STATUS
SCOTT RIVER			
	Oro Fino Creek #1	Oro Fino Valley Road	Not fish-bearing
	Oro Fino Creek #2	Lighthill Road	Not fish-bearing
	Sniktaw Creek #1	Quartz Valley Road	No crossing
	Sniktaw Creek #2	Quartz Valley Road	No crossing
	Sniktaw Creek #3	Quartz Valley Road	No crossing
	Sniktaw Creek #4	Big Meadows Road	**SURVEYED**
	Alder Creek	Big Meadows Road	Not fish-bearing
	French Creek – Eaton lakes tributary	French Creek Road	**SURVEYED**
	Patterson Creek	Patterson Creek Road	No, private road
	Rattlesnake Creek	Rattlesnake Creek Road	**SURVEYED**
	Indian Creek	Indian Creek Road	Not county maintained
	Walla Walla Creek	Indian Creek Road	Not county maintained
	West Branch Indian Ck.	Indian Creek Road	Not county maintained
	Tennessee Gulch	Indian Creek Road	Not county maintained
	Mill Creek #1	Mill Creek Road	**SURVEYED**
	Mill Creek #2	Mill Creek Road	No, Forest Service road
	Mill Creek #3	Mill Creek Road	No, Forest Service road
	Mill Creek #4	Mill Creek Road	No, Forest Service road
	Meamber Creek	Scott River Road	**SURVEYED**
	Duzel Creek #1	Duzel Creek Road	**SURVEYED**
	Duzel Creek #2	Duzel Creek Road	Not county maintained
	Duzel Creek #3	Duzel Creek Road	Not county maintained
	Duzel Creek #4	Duzel Creek Road	Not county maintained
	Duzel Creek #5	Duzel Creek Road	Not county maintained
	Duzel Creek #6	Duzel Creek Road	Not county maintained
	Duzel Creek #7	Duzel Creek Road	Not county maintained
	Meadow Gulch	Gazelle-Callahan Road	Not fish-bearing
	McConaughy Gulch	East Callahan Road	Not fish-bearing
SHASTA RIVER			
	Gravel Pit Draw	Long Gulch Road	Not fish-bearing
	Greenhorn Creek	Mill Creek Road	Above dam with no passage
	Unnamed tributary to Greenhorn Creek	Greenhorn Road	Above dam with no passage
	Park's Creek	Slough Road	Not fish-bearing
	Oregon Slough	Ager Road	Not fish-bearing
	Juniper Creek #1	Schantz Road	Not county maintained
	Juniper Creek #2	Arroyo Drive	Not county maintained
	Juniper Creek #3	Rolling Hills Road	Not county maintained
	Willow Creek #1	Gazelle-Callahan Road	**SURVEYED**
	Willow Creek #2	Gazelle-Callahan Road	**SURVEYED**
	South Fork Willow Ck.	Gazelle-Callahan Road	**SURVEYED**

Table 4. Site ID numbers for 36 Siskiyou County culverts in the Klamath River Basin.

SITE ID #	STREAM NAME	ROAD NAME
#1	Merrill Creek	Salmon River Road
#2	Hotelling Gulch	Callahan-Cecilville Rd.
#3	Sixmile Creek	Callahan-Cecilville Rd.
#4	Trail Creek	Callahan-Cecilville Rd.
#5	Cronan Gulch	Sawyer's Bar Road
#6	Kelly Gulch	Sawyer's Bar Road
#7	White's Gulch	White's Gulch Road
#8	Robinson Gulch	Sawyer's Bar Road
#9	Ottley Gulch	China Grade Road
#10	Frying Pan Creek	China Grade Road
#11	Horse Creek	China Grade Road
#12	Slater Creek	Indian Creek Road
#13	Luther Gulch	Indian Creek Road
#14	Darkey Creek	Seiad Creek Road
#15	Walker Gulch	Ladd Road
#16	Mill Creek	Mill Creek Road
#17	Meamber Creek	Scott River Road
#18	Sniktaw Creek	Big Meadows Road
#19	Rattlesnake Creek*	Rattlesnake Creek Road
#20	French Creek – Eaton Lakes trib.	French Creek Road
#21	Duzel Creek	Duzel Creek Road
#22	Collins Creek	Walker Road
#23	Dona Creek	Walker Road
#24	McKinney Creek	Walker Road
#25	Little Humbug Creek	Walker Road
#26	Fish Gulch Creek	Beaver Creek Road
#27	Vesa Creek	Klamath River Road
#28	Clear Creek	Humbug Creek Road
#29	Middle Fk. Humbug Ck.	Yreka-Walker Road
#30	South Fork Humbug Ck.	Yreka-Walker Road
#31	Willow Creek #1	Gazelle-Callahan Road
#32	South Fork Willow Ck.	Gazelle-Callahan Road
#33	Willow Creek #2	Gazelle-Callahan Road
#34	Williams Creek	Klamathon Road
#35	Cape Horn Creek	Copco Road
#36	Little Bogus Creek	Desevado Road

*Rattlesnake Creek at Rattlesnake Creek Road is a USFS-maintained stream crossing.

Table 5. Hydraulic capacity of 36 Siskiyou County road crossings. Capacity is expressed as both a discharge (cfs) and a return-interval (years) for flows overtopping culvert inlet (HW/D=1) and overtopping road prism (HW/F=1).

Site ID #	Stream Name	Road Name	Capacity at HW/D=1 (cfs)	Capacity at HW/F=1 (cfs)	Return Interval to Overtop Culvert (years)	Return Interval to Overtop Road Prism (years)
#1	Merrill Creek	Salmon River Road	**860**	**1,862**	**219**	**>250**
#2	Hotelling Gulch	Callahan-Cecilville Rd.	**62**	**99**	**5**	**9**
#3	Sixmile Creek	Callahan-Cecilville Rd.	**2,441**	**5,670**	**>250**	**>250**
#4	Trail Creek	Callahan-Cecilville Rd.	**804**	**1,636**	**>250**	**>250**
#5	Cronan Gulch	Sawyer's Bar Road	**2,366**	**2,366**	**>250**	**>250**
#6	Kelly Gulch	Sawyer's Bar Road	**177**	**241**	**14**	**26**
#7	White's Gulch	White's Gulch Road	**1,200**	**1,800**	**13**	**33**
#8	Robinson Gulch	Sawyer's Bar Road	**177**	**323**	**14**	**60**
#9	Ottley Gulch	China Grade Road	**64**	**107**	**6**	**11**
#10	Frying Pan Creek	China Grade Road	**64**	**91**	**5**	**7**
#11	Horse Creek	China Grade Road	**213**	**345**	**8**	**17**
#12	Slater Creek	Indian Creek Road	**112**	**202**	**6**	**15**
#13	Luther Gulch	Indian Creek Road	**276**	**523**	**12**	**53**
#14	Darkey Creek	Seiad Creek Road	**55**	**166**	**4**	**14**
#15	Walker Gulch	Ladd Road	**154**	**279**	**20**	**117**

Table 5 (continued). Hydraulic capacity of 36 Siskiyou County road crossings. Capacity is expressed as both a discharge (cfs) and a return-interval (years) for flows overtopping culvert inlet (HW/D=1) and overtopping road prism (HW/F=1).

Site ID #	Stream Name	Road Name	Capacity at HW/D=1 (cfs)	Capacity at HW/F=1 (cfs)	Return Interval to Overtop Culvert (years)	Return Interval to Overtop Road Prism (years)
#16	Mill Creek #1	Mill Creek Road	**353**	**440**	**4**	**4**
#17	Meamber Creek	Scott River Road	**70**	**100**	**5**	**7**
#18	Sniktaw Creek #4	Big Meadows Road	**313**	**397**	**8**	**11**
#19	Rattlesnake Creek*	Rattlesnake Creek Road	**144**	**210**	**4**	**6**
#20	French Ck. – Eaton lakes tributary	French Creek Road	**22**	**50**	**3**	**4**
#21	Duzel Creek #1	Duzel Creek Road	**1,162**	**1,815**	**18**	**60**
#22	Collins Creek	Walker Road	**64**	**194**	**3**	**6**
#23	Dona Creek	Walker Road	**31**	**51**	**3**	**3**
#24	McKinney Creek #1	Walker Road	**132**	**184**	**3**	**3**
#25	Little Humbug Creek	Walker Road	**210**	**270**	**4**	**4**
#26	Fish Gulch Creek	Beaver Creek Road	**64**	**67**	**4**	**4**
#27	Vesa Creek	Klamath River Road	**880**	**1,360**	**58**	**>250**
#28	Clear Creek	Humbug Creek Road	**26**	**30**	**3**	**3**
#29	Middle Fk. Humbug Ck.	Yreka-Walker Road	**313**	**541**	**6**	**13**

* Rattlesnake Creek is a USFS-maintained stream crossing.

Table 5 (continued). Hydraulic capacity of 36 Siskiyou County road crossings. Capacity is expressed as both a discharge (cfs) and a return-interval (years) for flows overtopping culvert inlet (HW/D=1) and overtopping road prism (HW/F=1).

Site ID #	Stream Name	Road Name	Capacity at HW/D=1 (cfs)	Capacity at HW/F=1 (cfs)	Return Interval to Overtop Culvert (years)	Return Interval to Overtop Road Prism (years)
#30	South Fork Humbug Ck.	Yreka-Walker Road	**213**	**412**	**6**	**15**
#31	Willow Creek #1	Gazelle-Callahan Road	**655**	**655**	**8**	**8**
#32	South Fork Willow Ck.	Gazelle-Callahan Road	**370**	**425**	**8**	**8**
#33	Willow Creek #2	Gazelle-Callahan Road	**104**	**151**	**6**	**6**
#34	Williams Creek	Klamathon Road	**840**	**1,840**	**53**	**>250**
#35	Cape Horn Creek #1	Copco Road	**340**	**695**	**13**	**37**
#36	Little Bogus Creek #1	Desevado Road	**1,088**	**1,760**	**47**	**209**

Passage Analyses

The **GREEN**-**GRAY**-**RED** first-phase evaluation filter reduced the number of sites requiring in-depth analyses with FishXing. Twenty-five of 36 sites (69%) were defined as **RED**, or failing to meet CDFG's fish passage criteria for adult and juvenile salmonids throughout the entire range of migration flows (CDFG 2001). It is important to note that a crossing which failed to meet the criteria may still actually provide partial or temporal passage during certain flow conditions. However, all **RED** sites were given a "total barrier" score in the ranking matrix.

Only a single stream crossing was defined as **GREEN** with the first-phase evaluation filter, Willow Creek #2/Gazelle-Callahan Road. This culvert was fully embedded with natural stream substrate and did not constrict channel width through the crossing. However, this culvert was extremely undersized (100% of inlet height on a six-year storm flow) and has poor alignment with the upstream channel. Due to these factors, this site is a likely candidate for plugging with storm debris and overtopping (and possibly damaging) the road prism.

FishXing proved an extremely useful tool in estimating the extent of passage at the 10 **GRAY** sites and identifying the probable causes of blockages. However, like most models which attempt to predict complex physical and biological processes with mathematics, there were limitations and assumptions that must be acknowledged.

Over the past five winters, repeated visits to numerous culverts within the Five-Counties region during migration flows revealed some confounding results generated by FishXing:

1. Adult salmonids having great difficulties entering culverts which FishXing suggested were easily within the species' leaping and swimming capabilities.

2. Adult salmonids successfully migrating through water depths defined as "too shallow" by current fish passage criteria.

3. The behavior and abilities of fish are too varied and complex to be summed up with an equation or number taken from a published article. Even a single fishes' leaping and swimming abilities at a culvert may change as numerous attempts are made. Five seasons of extensive winter-time observations at culverts in the Five-Counties region have documented individual fish become fatigued over repetitive attempts, and conversely documented other fish gaining access to culverts after numerous failed attempts (Taylor 2000 and 2001; Love pers. comm.).

Due to these factors, passage evaluation results generated by FishXing were used conservatively in the ranking matrix by lumping "percent passable" into large (20%) categories. Adult steelhead and coho salmon were lumped as the "adult" run, resident coastal rainbow trout and two-year old (2+) steelhead were grouped as the "resident trout" run, and one-year old (1+) and young-of-the-year (y-o-y) steelhead and coho salmon were grouped as the "juvenile" run.

Passage results generated by FishXing and the first-phase evaluation filter are displayed as "percent passable" for the range of migration flows calculated for each stream crossing location within six sub-regional categories (Klamath River tributaries downstream of the Scott River confluence, Klamath River tributaries upstream of the Scott River confluence, Indian Creek and Humbug Creek tributaries, Salmon River tributaries, Scott River tributaries, and Shasta River tributaries) (Figures 6-11).

For each site, by species and lifestage, FishXing evaluation results are provided in Appendix C. The "Comments" column in Appendix C lists assumptions made concerning specific **GRAY** sites while running FishXing.

Most culverts, 35 of 36 (or 97%), evaluated were at least temporary or partial barriers to adults salmonids. Twenty-eight of the 36 culverts (77.7%) failed to meet fish passage criteria over the entire range of migration flows and were considered total barriers to all adult and juvenile salmonids.

By species, six of 36 sites within the seven streams presumed to support coho salmon were estimated to be significant adult barriers (not passable on >60% of estimated migration flows) which block or inhibit migration to 11.9 miles of upstream habitat.

For steelhead (within 35 streams presumed to support steelhead), 34 of 36 sites were estimated to be significant adult barriers (not passable on >60% of expected migration flows) which block or inhibit migration to 47.2 miles of upstream habitat

For young-of-year juveniles, 33 of 36 (or 91.6%) culverts were classified as total migration barriers over the range of expected migration flows. For both age classes of juveniles, their extremely small size renders them most vulnerable to perched culverts or those with velocities during migration flows exceeding two to four feet per second.

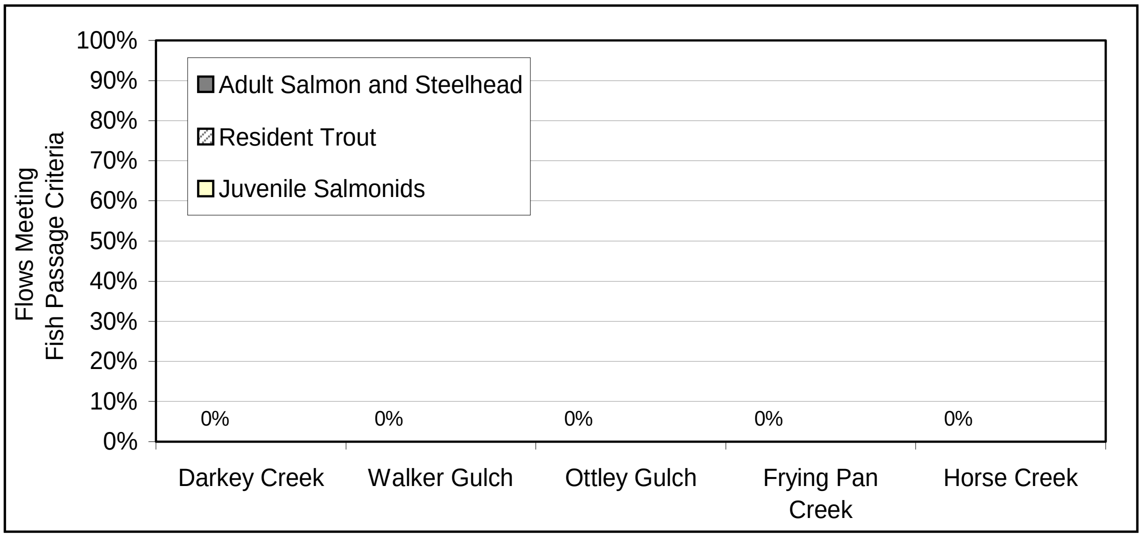


Figure 6. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter for five Siskiyou County stream crossings located on Klamath River tributaries downstream of the Scott River confluence, by life stages.

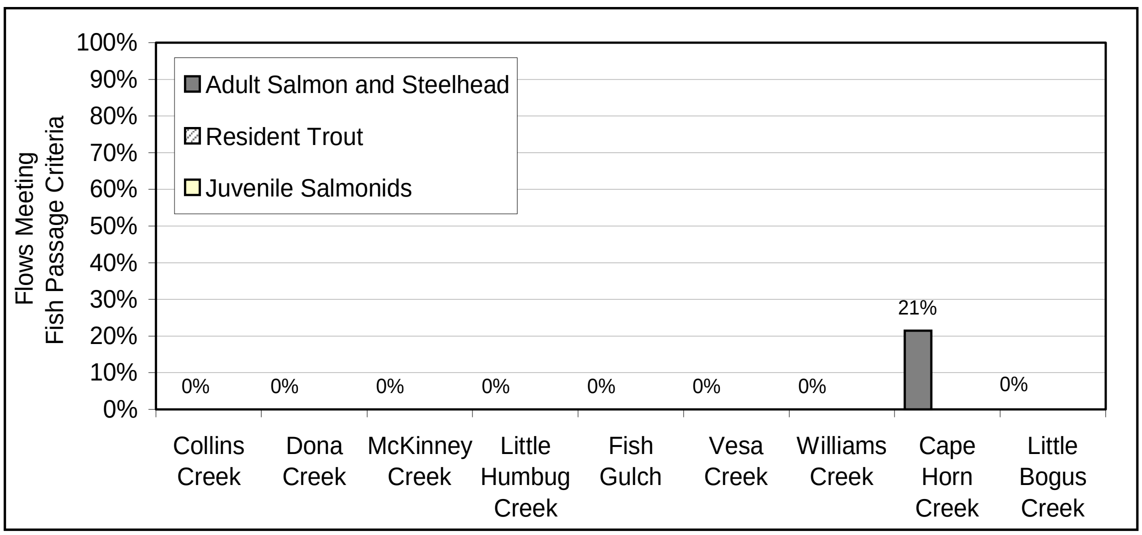


Figure 7. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter and FishXing for nine Siskiyou County stream crossings located on Klamath River tributaries upstream of the Scott River confluence, by life stages.

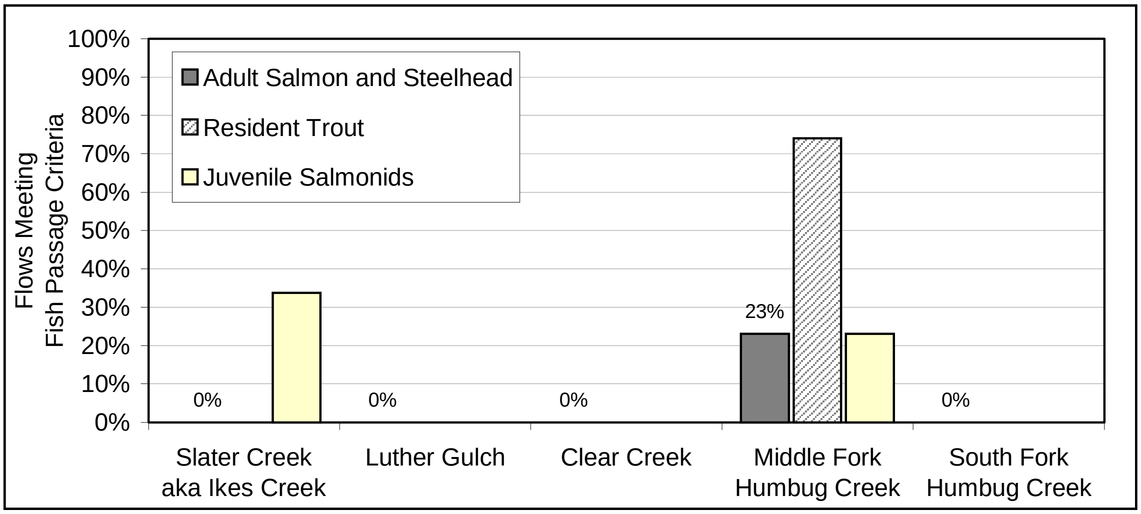


Figure 8. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter and FishXing for five Siskiyou County stream crossings located on Indian Creek (Slater and Luther Creeks) and Humbug Creek tributaries, by life stages.

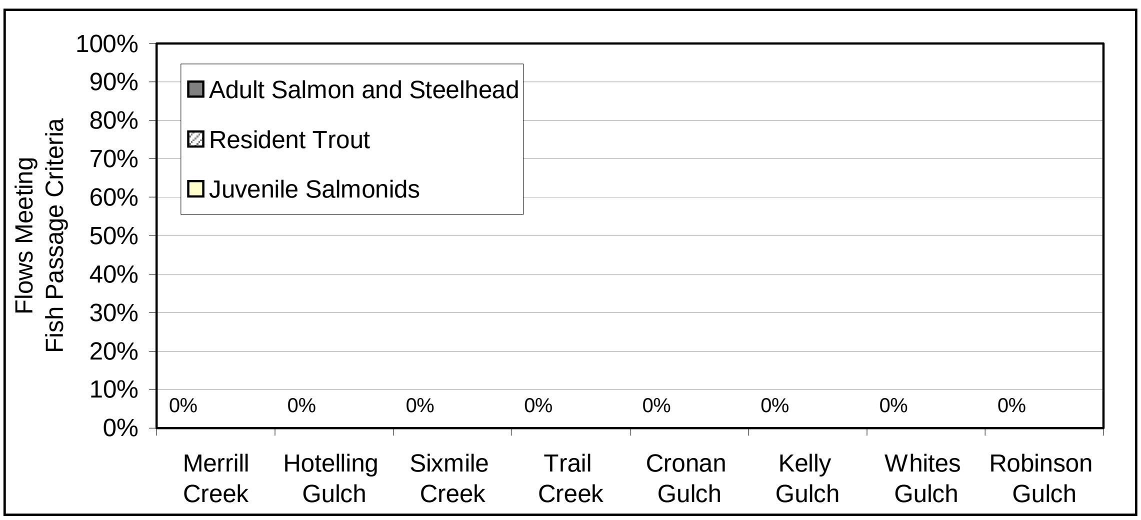


Figure 9. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter for eight Siskiyou County stream crossings located on Salmon River tributaries, by life stages.

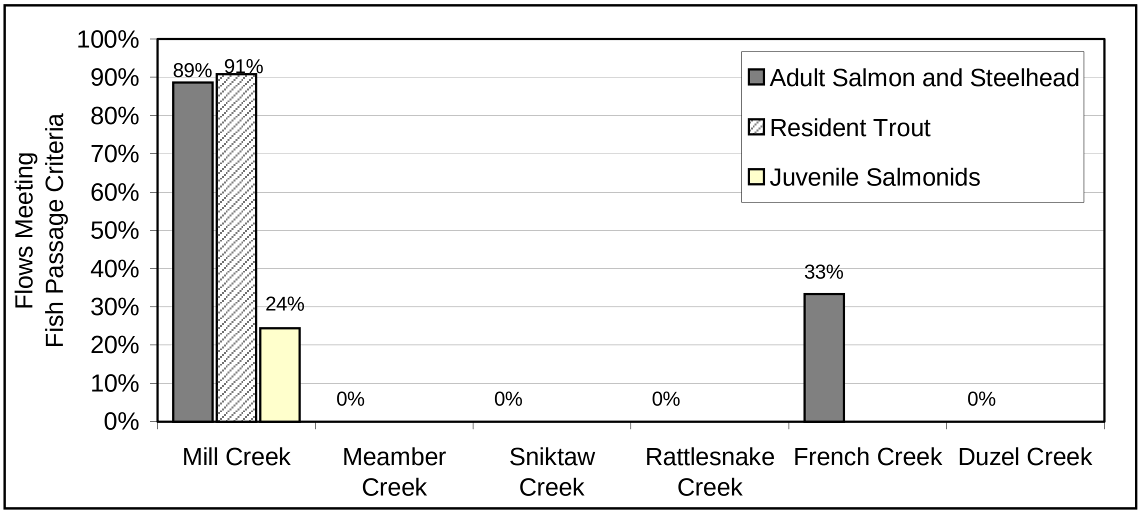


Figure 10. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter and FishXing for six Siskiyou County stream crossings located on Scott River tributaries, by lifestages.

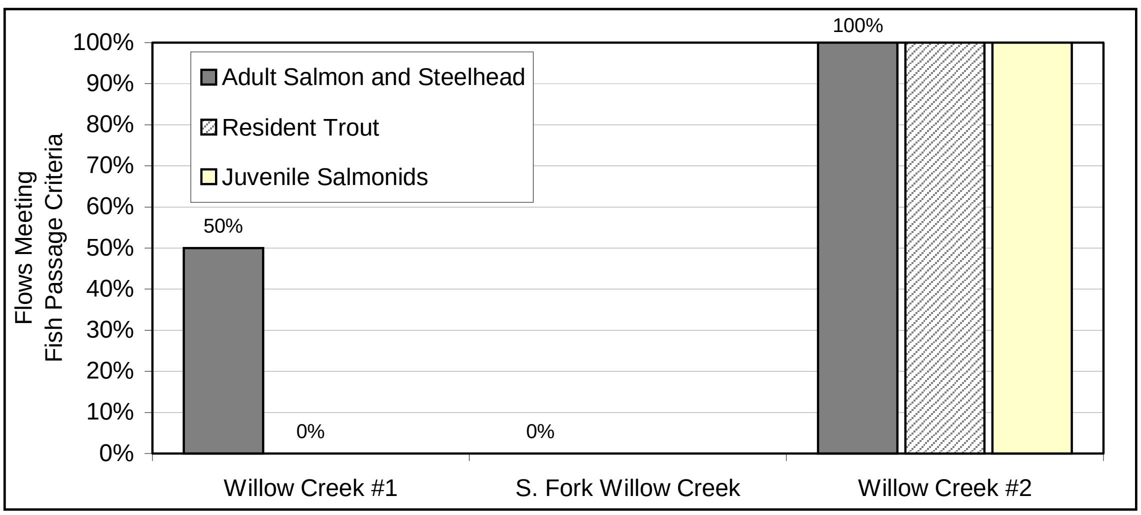


Figure 11. Percent passable as estimated by the GREEN-GRAY-RED evaluation filter and FishXing for three Siskiyou County stream crossings located on Shasta River tributaries, by lifestages.

Fish Observations

Fish observations were conducted at eight culvert locations during the winter of 2001-2002, for a total of 1,800 minutes (Table 5).

During earlier passage studies within the Five-Counties region, numerous observations have provided valuable insight into salmonid migration, including:

1. Most upstream migration occurred during the falling limb of storm hydrographs.

2. Regardless of jumping abilities cited in literature, most perched culverts were migration problems for adult salmonids. Site-specific hydraulics at culvert outlets appeared to create confusing flow patterns to migrating salmonids.

3. When individual fish made repeated jump attempts, these often occurred at regular intervals spaced about five to 12 minutes apart and often occurred at the same location. Individuals were rarely observed attempting leaps from a variety of locations at an outlet.

4. Although most literature on fall/winter, upstream movement of juvenile salmonids concerned only coho salmon, we observed upstream movement of three year-classes of either juvenile coastal cutthroat trout or steelhead (young-of-year, 1+, and 2+) at several culverts.

Merrill Creek was the only site in Siskiyou County where fish were observed attempting to migrate upstream. A large storm occurred on February 19, 2002 and the adult steelhead were observed leaping at the Merrill Creek site on February 20th and 21st. There appeared to be at least five or six individual steelhead attempting to migrate upstream. A site visit was conducted on February 22nd and no fish were observed – these adults most likely moved out of Merrill Creek when the storm flows receded and left to find other suitable spawning habitat.

These observations provided the following useful information:

During the winter of 2001-2002, the window for fish migration was quite narrow into Salmon River tributaries. The February 19-21, 2002 storm was the only winter storm when steelhead were observed. Visits were made to Merrill Creek during three other storm events and no fish were observed. Thus, providing unimpeded access is a vital component of any stream crossing remediation project.

When the Merrill Creek/Salmon River Road culvert is replaced with a bridge there is a high likelihood of immediate re-utilization of the upstream habitat by adult steelhead. Thus, this site was moved higher in the overall ranking of sites for treatment.

Table 6. Observations of salmonid migration at 11 culverts on the Siskiyou County road system, December 2001 – March 2002.

Stream Name	# of Visits	Total Obs. (minutes)	Adult Successful Attempts	Adult Failed Attempts	Juvenile Successful Attempts	Juvenile Failed Attempts	Comments
Merrill Creek at Salmon River Road	7	390	0	31	0	0	Adult steelhead observed on 2/20-21/02. At least five to six individuals observed. None observed on 2/22.
Hotelling Gulch at Cecilville Road	6	330	0	0	0	0	Juveniles were observed below the culverts, yet no leap attempts were observed.
Kelly Gulch at Sawyer's Bar Road	5	300	0	0	0	0	Below the county culvert, Kelly Gulch's flow is disconnected to the North Fork Salmon River by the FS spur road.
White's Gulch at White's Gulch Road	5	300	0	0	0	0	No fish observed. Turbulent conditions observed at channel drop into culvert inlet.
South Fork Humbug Creek at Yreka-Walker Road	2	120	0	0	0	0	Turbulence and high velocities at inlet drop were observed. Outlet was backwatered.
Williams Creek at Klamathon Road	2	120	0	0	0	0	Sheet flow through the right bank culvert was ≈ 0.5' deep and had a surface velocity of nearly six feet per second.
McKinney Creek at Walker Road	2	120	0	0	0	0	No fish observed during two visits. Culverts appeared passable, except for increased velocities at inlet drops.
Dona Creek at Walker Road	2	120	0	0	0	0	Appears adult steelhead would have difficulty accessing the Dona Creek channel unless the Klamath was quite high.

Ranking Matrix

Of the 36 culverts included in the inventory, 33 were included in the priority ranking. Three sites were dropped from the ranking matrix after further investigation produced the following information.

1. Fish Gulch/Beaver Creek Road. Past CDFG surveys have found no fish in this creek. Approximately 300' of channel on each side of Beaver Creek Road was examined during the initial site visit: no fish were observed; channel was narrow, steep, confined, and over-grown with brush and Himalayan blackberries. The channel itself appears to seasonally transport water, yet lacks any defined habitat features. Siskiyou County Department of Public Works should note that the culvert and road prism overtop on only a four-year storm and should be considered a high risk for failure.

2. Cronan Gulch/Sawyer's Bar Road. Past CDFG and USFS surveys have found no fish in this creek and described the channel as too steep for significant anadromous use. Approximately 300' of channel on each side of Sawyer's Bar Road was examined during the initial site visit: no fish were observed; channel was narrow, extremely steep, confined, and bedrock/boulder dominated. The channel immediately above the concrete box culvert was comprised of a series of cascades and falls. The crossing is adequately sized, passing greater than a 250-year storm flow.

3. Rattlesnake Creek/Rattlesnake Creek Road. It was later determined that this stream crossing is under USFS management. The sign "End of County Maintained" is located approximately 200 feet away from the stream crossing. The survey data and passage evaluation for this crossing have been provided to the Klamath/Trinity Forest Service Office in Fort Jones since this concrete box culvert is extremely undersized, fails to meet CDFG's fish passage criteria at all migration flows for adults and juveniles, and blocks migration to a significant reach of high-quality anadromous habitat.

The 33 Siskiyou County culvert locations were initially sorted by "Total Scores", the sum of the five ranking criteria: Presumed Species Diversity, Extent of Barrier, Current Sizing, Current Condition, and Total Habitat (Appendix D). To better assess biological significance of each stream, the 33 sites were also ranked by summing and totaling scores of the three "biological" criteria – Presumed Species Diversity, Extent of Barrier, and Total Habitat (Appendix D).

The final ranked list of the Siskiyou County culverts reflects changes made due to professional judgment (Table 6). These final ranking scores are included for each site in Appendix B – *Siskiyou County Culvert Catalog*.

Table 6. Ranking for 33 culvert locations on the Siskiyou County road system.

FINAL RANK	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
1	White's Gulch	White's Gulch Road	**2nd**	High-priority due to: severity of barrier = "RED" for all species and life stages; good habitat quality and significant length of upstream habitat gain (≈ 4.8 miles). Current culvert is undersized. Unimpeded access should be a high priority for all fish-bearing Salmon River tributaries. Has potential for steelhead and coho salmon, possibly chinook salmon. NOTE: there are six (non-county) upstream road crossings and a dam that should be evaluated for passage too. However the White's Gulch Road crossing is the lower-most impediment and should be treated first.
2	Merrill Creek	Salmon River Road	**Tied for 5th**	High-priority site due to: severity of barrier (the 5' to 6' perched outlet is likely a 100% barrier for all species and life stages) and significant length of high-quality upstream habitat gain (≈1.5 to 1.7 miles). Unimpeded access should be a high priority for all fish-bearing Salmon River tributaries. This site was initially ranked lower due to low scores for sizing and condition, but was moved higher due to biological potential (tied for 1st on biological criteria). Adult steelhead observed leaping unsuccessfully at culvert in 2/02. NOTE: Project for replacement bridge is funded and scheduled for construction in summer of 2002.
3	South Fork Humbug Creek	Yreka-Walker Road	**1st**	High-priority due to: severity of barrier = "RED" for all species and life stages; significant amount of blocked upstream habitat (approximately 0.7 miles); and has potential to support both coho salmon and steelhead. Culvert is undersized and in **very** poor condition. Site was dropped slightly in rank because of lesser length of upstream habitat gains versus Merrill Creek and Whites Gulch.
4	Hotelling Gulch	Cecilville Road	**4th**	High-priority due to: severity of barrier = "RED" for all species and life stages; quantity and quality of upstream habitat. Current culvert is undersized and in poor condition, with other problems associated with road drainage. Crossing is also located near the mouth of Hotelling Gulch – effectively blocking access to the creek's entire 1.4 mile reach of habitat. Project should assess current location and condition of lower channel.
5	Williams Creek	Klamathon Road	**Tied for 5th**	High-priority due to: failed to meet passage criteria over all migration flows of expected species (steelhead and coho salmon) and all life stages with over two miles of upstream habitat. The concrete box culvert is adequately sized, thus improving passage at this site requires a relatively inexpensive modification to the existing structure. Corner baffles and a notched outlet bean within the culvert and an outlet pool weir are recommended to increase water depths and decrease velocities within the culvert.
6	Kelly Gulch	Sawyer's Bar Road	**6th**	High-priority due to: severity of barrier = "RED" for all species and life stages; potential species diversity of stream (coho and steelhead); condition and sizing of current culvert; and quantity/quality of upstream habitat. Treatment of this crossing should also address reconstruction of the downstream channel that is disconnected to the North Fork Salmon River by a USFS-maintained spur road. This location is also impacted by knapweed and any ground disturbance must address minimizing the spread of this exotic, noxious weed.

Table 6 (continued).

FINAL RANK	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
7	McKinney Creek	Walker Road	**3rd**	High-priority due to: severity of barrier = "RED" for all species and life stages and length of upstream habitat (over 2.0 miles). This crossing initially ranked higher because it is in poor condition and extremely undersized – inlet and road prism are overtopped on less than a five-year storm flow. Site's rank was decreased because of its lower biological ranking (#5) that presumes steelhead is the only anadromous species to utilize this stream.
8	Little Humbug Creek	Walker Road	**Tied for 5th**	High-priority due to: severity of barrier = "RED" for all species and life stages and significant length of upstream habitat gain (1.5 to 1.7 miles). Crossing is extremely undersized. NOTE: Culvert on Walker Road was replaced with a bridge by Siskiyou County Public Works during summer of 2000. Before-and-after photos are included in Appendix B.
9	Middle Fork Humbug Creek	Yreka-Walker Road	**9th**	High-priority due to: although this culvert allows some passage for all species and life stages it was raised in the ranking because of the greater amount of habitat upstream compared to Horse, Darkey, and Collins Creek. Middle Fork supports steelhead and could be utilized by coho salmon. The upper reach of creek has good water quality during summer months for salmonids. Culvert is also undersized. Public Works should consider feasibility of treating this site concurrently with South Fork Humbug Creek, located approximately 150 feet to the west of Yreka-Walker Road.
10	Clear Creek	Humbug Creek Road	**11th**	High-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary. Current culvert and road prism are extremely undersized, overtopping on a three-year storm flow. Modification of the lower channel between the County road and Humbug Creek to improve passage should be evaluated as part of a culvert replacement project. Reports indicate an old mining dam located between the road and creek mouth – current status of this structure is unknown. Historically, steelhead utilized approximately 1.6 miles of Clear Creek for spawning and rearing.
11	Meamber Creek	Scott River Road	**14th**	Moderate-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary. Current culvert overtops on a five-year storm flow. Historically, steelhead had access to approximately 2.2 miles of Meamber Creek for spawning and rearing. The four private crossings located upstream of the county road should be assessed for passage before the County commits to a replacement of the Scott River Road crossing.
12	Collins Creek	Walker Road	**7th**	Moderate-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use this tributary. Current culvert overtops on a three-year storm flow. Historically, steelhead had access to approximately 1.5 miles of Collins Creek for spawning and rearing. Dropped in ranking due to lack of current observations of adult steelhead.

Table 6 (continued).

FINAL RANK	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
13	Sniktaw Creek	Big Meadows Road	**15th**	Moderate-priority - although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary. Current culvert is undersized.
14	Dona Creek	Walker Road	**8th**	Moderate-priority due to although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – probably only in years of high and/or frequent rainfall. Site also initially ranked higher because it is in poor condition and is extremely undersized: both the culvert and road overtop on a three-year storm flow. In May of 2001, hundreds to thousands of Klamath River juvenile salmonids were observed in Dona Creek's coolwater plume. Creek may have potential as coolwater refugia.
15	Horse Creek	China Grade Road	**13th**	Moderate-priority due to: severity of barrier = RED for all species and life stages) and significant length of potential upstream habitat gain (≈ 1.9 miles). Crossing is in poor condition and undersized – inlet overtops approximately an eight-year storm flow.
16	Little Bogus Creek	Desevado Road	**17th**	Moderate-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – probably only in years of high and/or frequent rainfall. The concrete box culvert is adequately sized, thus improving passage at this site requires a relatively inexpensive modification to the existing structure. Corner baffles and a notched outlet bean within the culvert and an outlet pool weir are recommended to increase water depths and decrease velocities within the culvert.
17	Duzel Creek	Duzel Creek Road	**19th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – probably only in years of high and/or frequent rainfall. The upstream habitat is in poor condition – but there is over five miles potentially available. Thus, the site was raised in priority over other streams with limited reaches of poor habitat.
18	Darkey Creek	Seiad Creek Road	**10th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 1,800') of poor habitat. Culvert is extremely undersized, in poor condition, and due for replacement.
19	Slater Creek	Indian Creek Road	**12th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a 4,100' reach of poor habitat. Culvert is undersized, in poor condition, and due for replacement.

Table 6 (continued).

FINAL RANK	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
20	South Fork Willow Creek	Gazelle-Callahan Road	**18th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a 1.6 mile reach of poor habitat. There are numerous probable migration barriers downstream of this crossing due to agricultural diversion dams and canals. Culvert is undersized, but is in good condition because it is a relatively new installation.
21	Frying Pan Creek	China Grade Road	**Tied for 20th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 500') of poor habitat.
22	Ottley Gulch	China Grade Road	**Tied for 20th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 500') of poor habitat.
23	Luther Gulch	Indian Creek Road	**15th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 2,800') of poor habitat. The current status of water quality and copper toxicity from past mining is unknown.
24	French Creek – Eaton Lakes' tributary	French Creek Road	**22nd**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use this upper reach of French Creek – which has a limited reach ≈ 1,000'. Current culvert is extremely undersized and overtops on a three-year storm flow. Road overtops on approximately a four-year storm flow.
25	Willow Creek #1	Gazelle-Callahan Road	**Tied for 23rd**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has poor habitat. There are numerous probable migration barriers downstream of this crossing due to agricultural diversion dams and canals.
26	Mill Creek	Mill Creek Road	**Tied for 23rd**	Low-priority due to: current crossing allows for adult and juvenile passage on most migration flows. Site should be periodically inspected for condition. Culvert is undersized, when needed, replace with a properly-sized crossing. Downstream crossing at the Quartz Hill Mine should be addressed to improve salmonid access into Mill Creek. USFS crossings above the county should also be assessed for passage.
27	Walker Gulch	Ladd Road	**24th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 500') of poor habitat.

Table 6 (continued).

FINAL RANK	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
28	Sixmile Creek	Callahan-Cecilville Road	**25th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a steep reach of habitat of marginal importance. Remote location and large volume of fill prism also make a full replacement cost-prohibitive. Current culvert is in good condition and properly sized.
29	Cape Horn Creek	Copco Road	**26th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 2,100') of poor habitat.
30	Vesa Creek	Klamath River Road	**27th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a limited reach (≈ 2,800') of poor habitat.
31	Robison Gulch	Sawyer's Bar Road	**21st**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a steep reach of habitat of marginal importance.
32	Trail Creek	Callahan-Cecilville Road	**28th**	Low-priority due to: although the site was "RED" and failed to meet passage criteria over all migration flows, only steelhead are presumed to use tributary – which has a steep reach of habitat of marginal importance. Remote location and large volume of fill prism also make a full replacement cost-prohibitive. Current culvert is in good condition and properly sized.
33	Willow Creek #2	Gazelle-Callahan Road	**29th**	Low-priority due to: site was "Green" and assumed to allow passage on all migration flows. However, current culvert is undersized and overtops on approximately a six-year storm flow. The culvert is also in poor alignment with the upstream channel which may lead to plugging of storm debris and increase likelihood of failure.

Site-Specific Treatments and Scheduling

High-Priority Sites

During the past few years, several sources of restoration funds have been available for treating priority migration barriers at road crossings – SB271, California Coastal Salmon Recovery Program (CCSRP), and Proposition 13 (Clean Water Bond). Siskiyou County has already treated, or has received funding to treat, two of the high-priority ranked sites. A bridge was constructed at Little Humbug Creek on Walker Road in the summer of 2000. A bridge for Merrill Creek on Salmon River Road is funded and scheduled for construction during the summer of 2002. It is recommended that proposals for several of the remaining nine high-priority sites be submitted to CDFG-administered funding sources in May of 2002.

For the 10 "high-priority" sites, recommendations are for nine replacements. Williams Creek is the only suitable candidate for modification of existing the crossing with corner baffles, an outlet beam, and a downstream boulder weir.

All culvert replacements should follow recently developed state criteria and federal guidelines for facilitating adult and juvenile fish passage (Heise 2001; NMFS 2001). However, site-specific characteristics of the crossing's location should always be carefully reviewed prior to selecting the type of crossing to install. These characteristics include local geology, slope of natural channel, channel confinement, and extent of channel incision likely from removal of a perched culvert.

For additional information, Bates et al. (1999) is recommended as an excellent reference to use when considering fish-friendly culvert installation options and Robinson et al. (2000) provides a comprehensive review of the advantages and disadvantages of the various treatment alternatives as related to site-specific conditions.

CDFG Allowable Design Options (from Heise 2001)

Active Channel Design Option is a simplified design method that is intended to size a crossing sufficiently large and embedded deep enough into the channel to allow the natural movement of bed-load and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing.

The Active Channel Design Option is suitable for the following conditions:

- New and replacement culvert installations
- Simple installations with channel slopes of less than 3%.
- Short culvert lengths (less than 100 feet).
- Passage is required for all fish species and life stages.

Culvert Setting and Dimensions

- **Culvert Width –** the minimum culvert width shall be equal to, or greater than, 1.5 times the active channel width.

- **Culvert Slope –** the culvert shall be placed level (0% slope).

- **Embedment –** the bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet. Embedment does not apply to bottomless culverts.

Stream Simulation Design Option

The Stream Simulation Design Option is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the crossing are intended to function as they would in a natural channel. Determination of the high and low fish passage flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the culvert.

Stream simulation crossings are sized as wide, or wider than, the bankfull channel and the bed inside the culvert is sloped at a gradient similar to that of the adjacent stream reach. These crossings are filled with a streambed mixture that is resistant to erosion and is unlikely to change grade, unless specifically designed to do so. Stream simulation crossings require a greater level of information on hydrology and topography and a higher level of engineering expertise than the Active Channel Design Option.

The Stream Simulation Design Option is suitable for the following conditions:

- New and replacement culvert installations.
- Complex installations with channel slopes less than 6%.
- Moderate to long culvert length (greater than 100 feet).
- Passage required for all fish species and life stages.
- Ecological connectivity is required.

Culvert Setting and Dimensions

- **Culvert Width –** the minimum culvert width shall be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than six feet.

- **Culvert Slope -** the culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6%.

- **Embedment –** the bottom of the culvert shall be buried into the streambed, not less than 30% and not more than 50% of the culvert height. Embedment does nor apply to bottomless culverts.

Substrate Configuration and Stability

- Culverts with slopes greater than 3% shall have the bed inside the culvert arranged into a series of step-pools with the drop at each step not exceeding 0.5 feet for juvenile salmonids.

- Smooth walled culverts with slopes greater than 3% may require bed retention sills within the culvert to maintain the bed stability under elevated flows.

- The gradation of the native streambed material or engineered fill within the culvert shall address stability at high flows and shall be well graded to minimize interstitial flow through it.

Hydraulic Design Option

The Hydraulic Design Option is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. The method targets specific species of fish and therefore does not account for ecosystem requirements of non-target species. There can be significant errors associated with estimation of hydrology and fish swimming speeds that are mitigated by making conservative assumptions in the design process. Determination of the high and low fish passage design flows, water velocity, and water depth are required for this option.

The Hydraulic Design Option requires hydrologic data analysis, open channel flow hydraulic calculations and information on the swimming ability and behavior of the target group of fish. This design option can be applied to the design of new and replacement culverts, and can be used to evaluate the effectiveness of retrofits for existing culverts.

The Hydraulic Design option is suitable for the following conditions:

- New, replacement, and retrofit culvert installations.
- Low to moderate channel slopes (less than 3%).
- Situation where either Active Channel Design or Stream Simulation Options are not physically feasible.
- Swimming ability and behavior of target fish species is known.
- Ecological connectivity is not required.
- Evaluation of proposed improvements to existing culverts.

For more information regarding the Hydraulic Design option, or to obtain the most recent copy of the CDFG *Culvert Criteria for Fish Passage*, contact the North Coast Regional Office at 601 Locust Street, Redding, CA 96001 (916)-225-2300.

NMFS Order of Preferred Alternatives

1. *No crossing* - relocate or decommission the road.

2. *Bridge* - spanning the stream to allow for long-term dynamic channel stability.

3. *Streambed simulation strategies* – bottomless arch, embedded culvert design, or ford.

4. *Non-embedded culvert* – this often referred to as a hydraulic design, associated with more traditional culvert design approaches limited to low slopes for fish passage.

5. *Baffled culvert or structure designed with a fish-way* – for steeper slopes.

For more information, or to obtain a copy of the NMFS *Guidelines for Salmonid Passage at Stream Crossings* go to the Southwest Region website at: http://swr.nmfs.noaa.gov

Moderate-Priority Sites

The "moderate-priority" tier of culvert locations requiring treatment to improve fish passage includes nine locations with ranks #11-16. The exact scheduling for treating the remaining "moderate-priority" sites is unknown at the time because:

1. Siskiyou County Public Works has a large task of developing proposals, securing funding, and completing the scheduling, contracting, permitting, and implementation required to treat the first 10 locations. The County should focus on completing these higher priority projects with properly designed and constructed treatments before addressing the next tier of sites.

2. Siskiyou County is a participant in the Five-Counties Salmon Group, which plans to acquire treatment funds for passage problems in all five counties (Siskiyou, Trinity, Mendocino, Del Norte, and Humboldt). Thus, the remaining "moderate-priority" tier of Siskiyou County culverts should be ranked and evaluated with respect to priority culverts located in the other four counties. Culvert inventories were completed in Humboldt, Del Norte, and coastal Mendocino counties. Trinity County's inventory is due for completion by June of 2002.

3. When addressing the "moderate-priority" tier of culverts, the current biological condition and/or importance (such as quantity) of the streams starts to diminish. Thus, these sites may not rank well compared to other types of projects proposed to state and federal funding sources. However, other sources of funding, such as urban stream programs should be considered. Sites in poor condition and/or undersized should be eventually treated with county maintenance and repair funds.

Low-Priority Sites

The remaining sites, ranked #17-33, are of "low-priority". These sites either permit fish passage, or have minimal biological benefit if treated. However, these sites should be examined for "consequence-of-risk" as to current condition, sizing, and fill amount. All future replacements with Public Works maintenance funds should include properly sized crossings that permit unimpeded passage of adult and juvenile salmonids.

The four most common activities impacting these Siskiyou County streams are timber harvesting, agriculture, unfenced grazing, and residential development. Most of these low-priority creeks generally exhibited some or all of the following characteristics:

1. Lack of pools and habitat complexity;
2. Denuded or non-existent riparian zones;
3. Extensive straightening, berming, and diking of channel;
4. High volumes of fine sediment; and
5. Warm summer water temperatures.

Limited fisheries restoration dollars should probably not be spent on improving fish passage in these streams, unless significant improvements occur to impacts of other land management activities. However, the County should carefully examine this list and determine which locations may be treated with existing maintenance funds.

For example, Siskiyou County Public Works may have a general plan for improvements to specific traffic corridors or routes. Also, when low-priority culverts fail during winter storms, planners should examine the sizing of the failed structure and budget for properly-sized replacements. When applying for FEMA funds, Siskiyou County Public Works should utilize this report to explain why the replacement should be a larger and higher-quality crossing (for both fisheries and future-flood benefits).

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